Greater Brighton Energy Plan: opportunities and challenges

Final Report

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Revision 02

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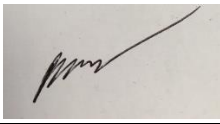
signature	
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1 Executive Summary

1.1 Introduction

On behalf of the Greater Brighton Economic Board (GBEB), Brighton & Hove City Council (BHCC) commissioned an analysis of the economic opportunities and challenges provided by energy across the Greater Brighton area, covering power, heat and transport. The primary focus of the Energy Plan is on carbon reduction. There is not the same attention given to affordability and to a somewhat less extent resilience. The challenge with the former being, particularly in the case of heat, zero carbon solutions are not the most economic approach. During the course of this work engagement and development of links with SGN, SSE and UKPN has already helped bring forward exemplar projects to build network resilience within the zero carbon transition. Maintaining and continuing to develop these links is seen as a major opportunity to ensure the Energy Plan progresses, in a manner which enhances network resilience and is economically viable.

The Energy Plan is based on the 5 themes described in the Tri-LEP Energy Strategy i.e. Energy Efficiency, Renewable Energy, Heat, Transport and Smart Energy. These are applied in a local context to assess projects and categorise them in the Greater Brighton region.

The analysis is based on scenarios that can deliver against national decarbonisation targets, reviewing the published National Grid Future Energy Scenarios. Of the four scenarios used by National Grid, only two meet the national targets, i.e. 2 Degrees and Community Renewables. The graph on the left of Figure 1—1describes the scenario for 2 Degrees. This assumes a centralised approach to decarbonisation through the deployment of large amounts of offshore wind, nuclear energy (SMRs) and decarbonisation of existing gas infrastructure through hydrogen (which increases rapidly in utilisation from about 2030). The graph on the right describes the Community Renewables scenario which has a far more decentralised approach relying on a combination of local and central initiatives but including the focus on energy efficiency, electrification of transport and heat and significant reduction of gas for heat.

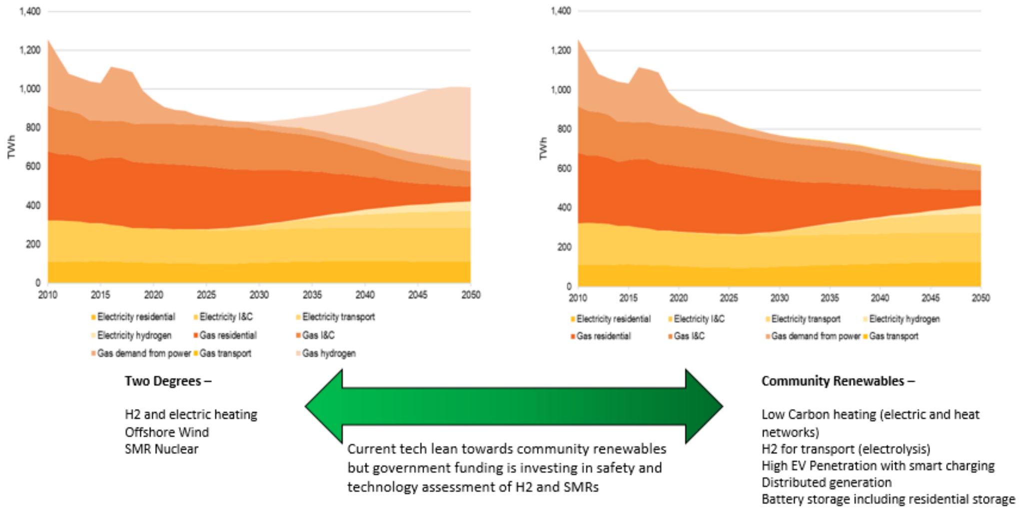

Figure 1—1 Summary of the National Grid Future Energy Scenarios.

Both approaches are considered feasible. However, it was agreed with the Greater Brighton Energy Working Group that the emphasis should be placed on a project pipeline that would deliver against the region's carbon objectives whilst supporting local economic growth, and also have the potential to be enabled through direct support and influence of the local authorities in the region. In considering this, it was felt that Community Renewables fitted far more closely with this remit, i.e. to develop a portfolio of local projects that fall within the five themes but that can be influenced locally by Local Authority involvement.

1.1.1 Scope of work

On behalf of the Greater Brighton Economic Board (GBEB), Brighton & Hove City Council (BHCC) commissioned this analysis, based on the following scope requirements:

1) Review of existing and previous Energy Plans completed at local authority, regional and national levels including the previously commissioned Tri-LEP reports.
2) Development of a project pipeline of opportunities in the Greater Brighton Region
3) Development of a solar road map
4) More detailed analysis of solar and storage opportunities
5) Identify delivery models for supporting the development and delivery of projects in the project pipeline
6) Analyse the project pipeline including development of a scenario that would allow the Greater Brighton region to deliver against national decarbonisation targets (noting that subsequent to the commissioning of this report a number of authorities have now also declared climate emergencies)

In developing a viable approach to the energy strategy, it was decided to continue on the basis of the 5 themes described in the Tri-LEP study i.e. Energy Efficiency, Renewable Energy, Heat, Transport and Smart Energy. These would however be applied in a more local context to assess projects and categorise them in the Greater Brighton region.

1.2 Key strategy areas

The core themes are based on the five focus areas of the 2018 Tri-LEP Energy Strategy. Key to the study process was information gathering, through questionnaires, workshops and meetings. Three workshops were held, focussing on e-mobility, decarbonisation of heat and decarbonisation of off-grid communities.

Low carbon heating – heating in the UK contributes to approximately 40% of carbon emissions, with the domestic sector itself contributing approximately 10%. In addition, the larger component of the average energy bill is due to the supply of heat (opportunities for waste heat utilisation are highlighted for further investigation). This was therefore a critical area to focus on with the electrification of heat and heat networks being seen as key enablers. Many decarbonisation of heat scenarios rely heavily on shifting from natural gas to hydrogen, however this requires centralised national strategy and has a long lead time. As an intermediate step hybrid heat pumps were identified as a key technology; causing immediate decarbonisation, whilst having the risk of creating stranded assets if a national transitional to hydrogen occurs. This is a complex issue, as at the moment the counterfactual scenario of gas for existing properties makes transitions generally uneconomic.

Energy saving and efficiency – scenario analysis shows energy saving and efficiency is key to achieving a zero carbon energy system. Greater Brighton and the Local Authorities which make it up have a significant role to play directly in terms of their own building stock, whilst local schemes, incentives and installers are key driving factors for achieving project uptake. Consequently, this is a key immediate priority for the energy plan. Efficiencies can be delivered through many different routes including building retrofits and intelligent control. In the case of heat, the use of heat pumps which due to their COP means the overall energy consumption is reduced compared to gas whilst the electrification of transport means round trip energy consumption is far lower.

Renewable generation – renewable generation is a complex area, with some of the key contributors in terms of quanta of low carbon electricity generated being external to a greater Brighton Energy Plan (notably offshore wind). However, distributed generation is a key element of the vast majority of projects identified – particularly those with a high level of readiness for deployment. Thus when it is being integrated with other key areas, renewable generation is an immediate priority area but large scale centralised generation is outside the plan.

Smart energy system – the smart energy system acts to bring together all aspects of the energy system and is vital if carbon targets are to be met. Discrete projects will not achieve the objectives. Such a system would, for example, include the integration of infrastructure with smart energy grids, smart buildings and intelligent tariff based solutions for energy consumption and EV charging. Smart systems are not included in the focus of this project area currently due to the complexity of multi-party integration. In itself it is not a discrete solution but any projects implemented should consider smart interfaces as core to the delivery strategy.

Transport revolution – Transport is seen as a key decarbonisation opportunity, being generally more rapidly achievable than heat due to existing policy drivers. Greater Brighton is seen as very well situated to deliver this transition. Brighton and Hove are progressing rapidly with electric vehicles and hydrogen buses, the learning and approaches can be disseminated among the rest of the Greater Brighton area to inform strategy. Moreover, the infrastructure requirements for low carbon transport means a cohesive area approach is important for successful implementation. A separate working group focusing on transport would be beneficial to achieving this.

1.2.1 Key projects

A list of 17 key project areas were identified throughout the research process. These could be termed either opportunities (as some present well established economically viable solutions) or requirements as some (particularly for heat) represent a challenge due to the relatively low cost currently for natural gas:

- **Solar schools** – community energy groups in the area have established a functioning business model for deploying solar on schools and providing power through a PPA. Local Authorities and One Public Estate could encourage school engagement and offer similar assets and projects. This could be applied to every school in Greater Brighton – meaning tens of MW of additional PV capacity.
- **Landfill solar** – utilises land that is low value, and often contaminated/unsuitable for other developments. Additionally, the land is often owned by the council, providing a potential revenue scheme and in some instances (Beddingham and Lindsey for Greater Brighton) already has electrical infrastructure that can be used.
- **Riding Sunbeams** – this company has multiple sites which will develop solar PV farms (with community investment) that will feed electricity directly into the rail network – providing power for traction. This represents a world leading project in this field.
- **Rural off gas grid communities** – developing low carbon solutions in off gas grid areas often represents the hardest challenge for electricity networks. Novel approaches, particularly for heat are being explored in projects at Firle and Barcombe. The novel approaches mean the Barcombe project (which is discussed as a

developed case study) is currently progressing through a Network Innovation funding application and could provide a model applicable to ~1.5 million homes across the UK.

- **Urban heat networks** – there are multiple project already in Greater Brighton, including some using novel marine heat pumps. An emphasis in the energy plan is placed on utilising waste heat resources, with large pollutant emitters (such as supermarkets, and water treatment sites) being identified as useful initial heat sources to consider.
- **Hydrogen for buses and HGVs** – hydrogen is seen as a suitable technology for heavy road transport. Electrolysis technology means it can be created using cheap renewable electricity. A case study is examined using cheap wind from the Rampion wind farm at the Bolney substation. This would become a hydrogen hub with the two main freight ports of Shoreham and Newhaven also being important hubs.
- **Solar car parks** – onsite generated PV can be used to charge electric vehicles. This could be rolled out across car parks. Train stations and supermarket car parks are seen as good initial opportunities to consider. The higher economic price for solar power sold via charging points than to the grid can help increase financial viability for solar post FiT.
- **Electric vehicle rollout** – a higher penetration of EVs is vital for achieving carbon targets. Brighton and Hove are one of the leading Local Authorities in the UK in this area and an official knowledge sharing platform is seen as vital to help achieve quick rollout of EV enabling systems.
- **Hybrid heat pumps** – hybrid heat pumps retain gas boilers but utilise heat pump technology for the majority of heat load. This maintains energy system resilience/security whilst causing substantial carbon savings. The relatively low price of gas means issues of fuel poverty may arise in the near term with this technology – meaning support mechanisms will need to be in place.
- **Retro-fits (building fabric)** – as with most of the UK the building stock in Greater Brighton has an EPC rating of D or lower. This needs to be improved to reach carbon targets. Pay as you go schemes, combined purchasing power, standardised approaches and local supply chain growth are all seen as enablers for this necessary and large-scale task (~200,000 homes would need improvement if all homes were to reach a C grade EPC).
- **Anaerobic digestion to create biogas** – injecting biogas into the grid created from waste sources can help green the gas grid. With the retention of the gas network for hybrid heat pumps this would help in greening the gas that is used.
- **Utilising the potential of large emitters** – these large emitters generate waste heat, that could be used in heat networks. The are also the largest point users of electricity in Greater Brighton, making them well suited to onsite generation (and potentially storage) to offset their grid requirements.
- **Batteries and localised generation in grid constrained areas** – constrained areas of the grid are now offering fiscal incentives to provide balancing services and flexibility, to avoid reinforcement. This opens up opportunities for local distributed schemes.
- **Domestic solar PV** – this is a well established technology and application which has stagnated of late due to the removal of the FiT. It is suggested that by bulk purchasing schemes to lower CAPEX, financial viability of schemes will improve.
- **Non-domestic solar PV** – this is referring to rooftop non-domestic PV, with the approach being the same as its domestic counterpart.
- **Biomass** – there is a well developed sustainable local biomass supply chain. This can be utilised and expanded for some applications such as off gas grid areas and in heat networks, providing fuel for biomass boilers.
- **Solar thermal** – the RHI is still in place providing support for solar thermal technology. Solar thermal is seen to have domestic application, non-domestic (with large heat uses such as leisure centres being seen as

particularly applicable) and potentially for heat networks (this is a theme currently in the early stages of exploration at BEIS).

1.3 Delivery themes

Although there are many different delivery/enabling opportunities in Greater Brighton three examples are picked out below:

1.3.1 Energy Investment Company/Abundance Investment model

Having a centralised strategic investment vehicle will help realise pipeline energy projects. It is suggested that the case for funding could be put through the City Deal framework. The Borderlands area of Scotland and England has recently been successful in attaining funding for the first stage of a similar project, a large part of the funding ask being for investment capital. The aim is to then attract outside investment, in addition to reinvesting profits from projects. The scale of a centralised Energy Investment Company (EIC) becomes a more attractive offer to large scale investors. A dedicated strategic EIC would also have the advantage of accepting lower rates of return than would often be looked for by traditional investors and could explore blended finance solutions for the risk stages of project development. The EIC would have a centralised panel, including central and local government and DNOs, which would make investment decisions. For Greater Brighton, an EIC formed of the wider infrastructure panel will help formalise the knowledge sharing process.

An agreed delivery vehicle linked to the Energy Investment Company could be a good choice to deliver carbon reductions and infrastructure resilience across the GBEB area. This could link with wider regional partnerships including the LEP, County Councils, NHS and Universities. The benefits of the investment vehicle in terms of scalability and a mixed public and private approach, can be applied to delivery vehicles also. On a smaller less formal scale we are seeing the benefits of a joined up approach across Sussex in the Your Energy Sussex partnership that has brought together local authorities to deliver an energy tariff scheme and is currently exploring a solar bulk purchase scheme for private households. A more formal commitment from member authorities to this kind of joint working could well deliver significant progress to meeting the ambitions of GBEB.

The delivery vehicle would need to have freedoms to secure funding from a variety of sources and deliver projects that can be scaled from one partner to the whole GBEB area. The scope can be determined to meet the local ambition and restrictions of varied areas with different governance and decision making structures. For example, it could be focussed on renewable energy projects as stand-alone carbon saving, energy resilience and fuel poverty alleviation to a more ambitious and broader scope taking in the connectivity offered through smart cities approach (transport, digital etc.).

Another model empowering a more crowdfunding based approach that could end up functioning to an EIC is that of community or Greater Brighton bonds. Particular note is given to the Abundance Investment model, with projects that would be suitable investable opportunities being flagged in the energy plan report. Having a project portfolio, for which the energy plan provides an initial basis, acts to increase scale - generally improving the investment opportunity and decreasing risk.

1.3.2 Combined purchasing power

Economies of scale means bulk purchasing of technologies can lead to substantial reductions in costs. This model is already in place through Solar Together and iChoosr for schemes in London, Sussex and elsewhere; where householders and SMEs register their interest to have solar PV installed on their roofs. With the support of Local Authorities these schemes can be pooled allowing a lower technology purchasing price. This driving down of costs for PV can help to overcome the challenges created for the sector by the removal of the feed-in tariff.

This approach of combined purchasing power could extend beyond solar from batteries to hybrid heat pumps. This would integrate well with another characteristic of the Solar Together scheme; that installation can be provided as well as the technology. A centralised government associated body like an EIC with trusted installers would help to increase consumer confidence, and thus uptake. This could be developed further with local installers and challenge the market, especially local installers, to create a supplier framework mechanism and to come up with a range of approved local solutions for supply and installation of solar energy that can be trusted by local residents.

1.3.3 Community energy groups

One of the most distinguishing features of the Greater Brighton area is the presence of five established active community energy groups. Ofgem flags these as key to delivery of successful local energy plans, with several of those operating within Greater Brighton being noted as exemplar models. Making these community energy groups central to the delivery strategy is seen as key to quickly realising projects in the Greater Brighton area. Also having them formally within the plan will assist with integrated Local Authority and community strategies, helping to remove any perceived conflicts.

1.3.4 Upskilling the workforce

Increasing demand for low carbon technologies, particularly the electrification of heat and transport, means increased skills are needed, for example, installation by heating engineers, energy efficiency retrofit. Existing SME support networks such as the Green Growth Platform and the Sustainable Business Network are ideally placed to assist local businesses to lower their own carbon emissions and are a resource for installers.

1.4 Scenario modelling

A model was built to undertake analysis of the impacts of projects and decisions on decarbonising Greater Brighton's energy system. These included specifically identified heat networks, an additional ~300 MW of solar generation in the Greater Brighton area, transition to low carbon transport (a mix of hybrid vehicles, EVs, and hydrogen busses and HGVs), energy efficiency, and heat pumps (the majority of which are hybrid to maintain the flexibility of gas in the system). Information is examined in terms of carbon and energy share.

1.4.1 Carbon impact

A baseline was established for carbon emissions using historic government data and then forecast taking into account information such as population growth and the impact of national and local policies and projects. The results are displayed in Figure 1—2.

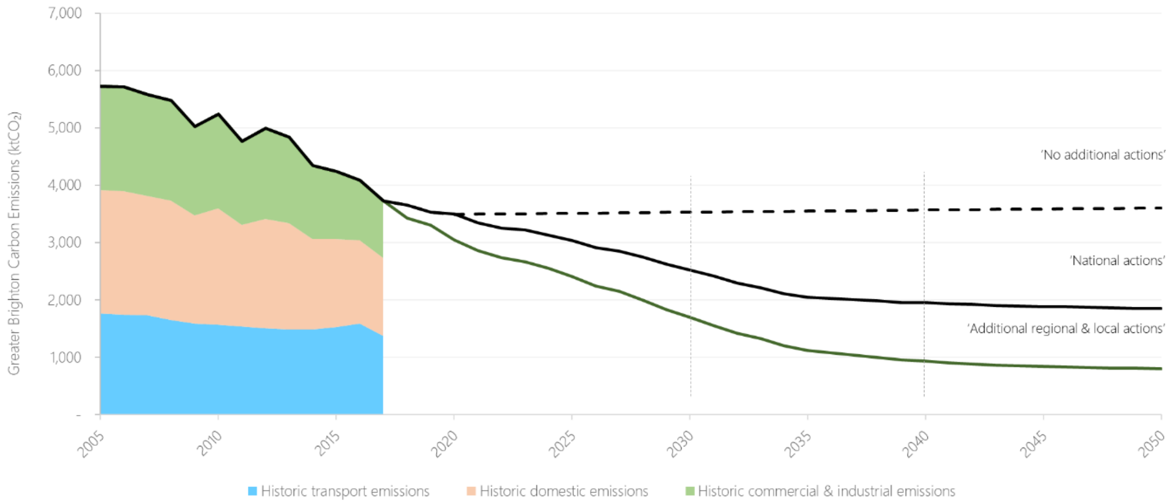

Figure 1—2 Impact of different policy approaches in decarbonisation of Greater Brighton.

Over the last decade, there has been a decrease in carbon emissions, mainly due to successful greening of the electricity grid. Therefore, for renewable electricity generation to be of maximum value, it has to be coupled with electrification of both the heat and transport sectors.

Figure 1—2 highlights that with no additional action there is a slight carbon growth, due to an increase in population and associated per capita emissions. National actions and policies achieve a reduction of ~1500 $ktCO_2$ per annum, comparing current and 2050 emissions. With additional local Greater Brighton based actions this drops by a further ~1000 $ktCO_2$, to just under 1000 $ktCO_2$. So even with an aggressive decarbonisation approach (particularly in terms of heat compared to national policy) further action is needed to reach the zero-carbon target locally.

1.4.2 Energy share

Examination of the energy share of different sectors helps understanding of how transitions occur and where changes can be made to maximise decarbonisation. A summary of energy shares is presented in Figure 1—3 (this is for the same scenario as that presented in Figure 1—2).

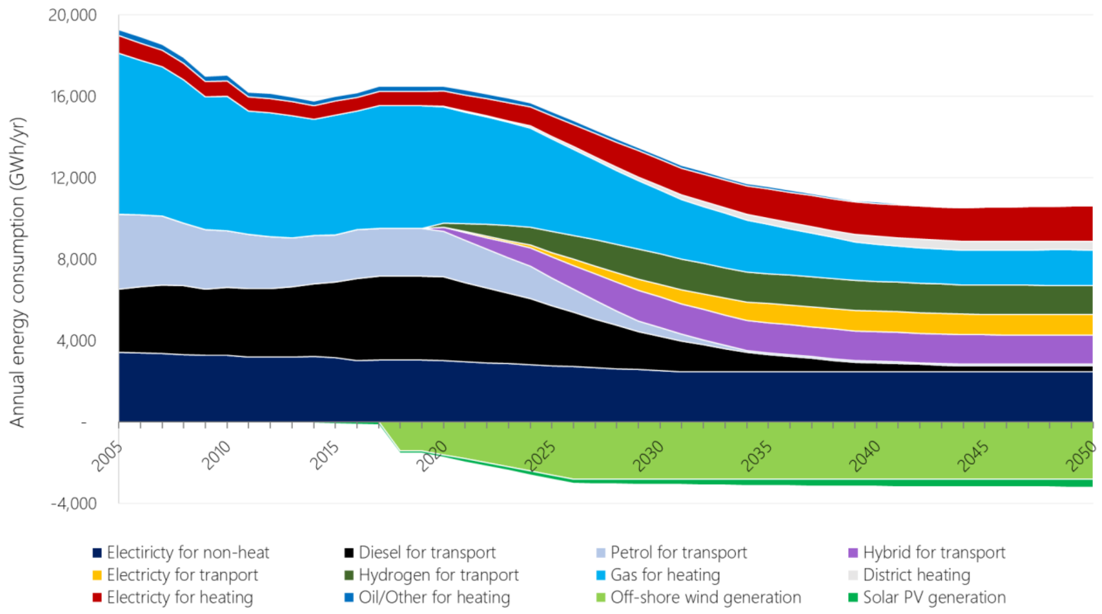

Figure 1—3 Energy demand for different energy system elements. This model is currently being updated to take into account the improved energy efficiency of low carbon transport compared to the combustion engine equivalent (for example, electric vehicles use one third of the equivalent energy of petrol cars to cover the same distance).

Figure 1—3shows the share of gas remains significant in 2050, due to the continued presence of hybrid heat pumps, but assumes no transition away from natural gas to hydrogen in the network. This is the most significant element in remaining carbon emissions displayed in Figure 1—2. Thus, important decisions will need to be made about a full transition to electric heat (with high associated electricity infrastructure costs), or decarbonisation of the gas grid. Hybrid heat pumps assist with transition to either of these scenarios and help to delay this significant policy choice; but they still require concerted effort to move away from gas, which is currently the lowest cost option.

The potential of low carbon generation is explored in the green sections at the bottom of Figure 3. Substantial renewable electricity is provided by the Rampion offshore wind farm, with the increase to 2027 coming from the planned extension of the site. Whilst the Rampion wind farm is not included in the carbon analysis or the Energy Plan (due to Greater Brighton's limited influence) it is illustrated in the energy share to give perspective to the relative contribution of solar PV. The modelled PV equates to over 300MW of additional installed capacity from current levels by 2050, compared to the 800MW of capacity for Rampion (with the extension). The difference is exacerbated by the substantially higher capacity factor for offshore wind, meaning that for each MW of capacity nearly four times the electricity will be generated in a year. Solar PV can still have a very important part to play in the low carbon transition for Greater Brighton, either through utilisation on site for small power and process demand or through decarbonising other energy vectors. This technology coupling for heat, e.g. providing power to heat pump systems, and transport, e.g. solar carparks and Riding Sunbeams, is seen as more beneficial than selling electricity to the grid where, as Figure 3 illustrates, centralised offshore wind provides a more viable alternative.

2 Introduction

2.1 The Greater Brighton area

The Greater Brighton region covers seven different Local Authority (LA) areas in south east England and is home to over 900,000 people, 400,000 jobs and 40,000 businesses. The extent of the region and the Local Authorities are displayed in Figure 2—1.

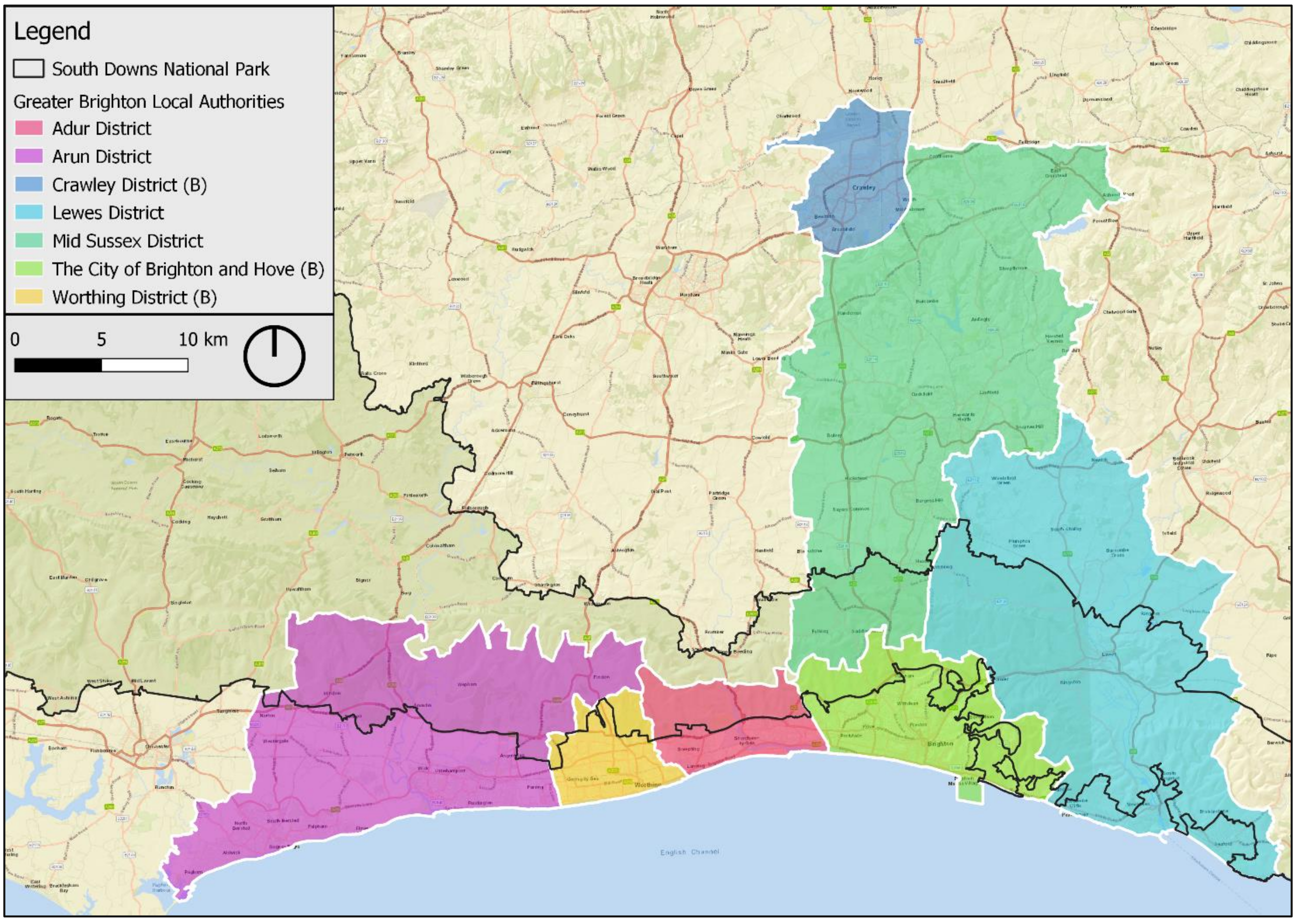

Figure 2—1 The Greater Brighton area.

As the map indicates there is a substantial variation in geography of Greater Brighton; containing urban areas, notably Crawley in addition to Brighton and Hove, as well as rural areas – predominantly in Mid Sussex and Lewes. The area, as shown in Figure 2—1 has the South Downs National Park running through it. The impact of this is discussed throughout the report but essentially large-scale renewable projects within the National Park are less likely to pass through the planning system. However, there is a strong political will in the area to make carbon reductions, with many of the LAs declaring climates change emergencies – aiming for 'net-zero'[1] wherever possible by 2030. This is

[1] 'Net-zero' refers to an overall balance of zero carbon emissions, so in addition to switching to low carbon energy and materials carbon be offset through carbon sequesting environments and projects – such as tree planting.

more ambitious than the 2019 central UK target of 'net-zero' by 2050, which again marked an increase from the previous 80% carbon reduction by 2050.

2.2 Project scope

On behalf of the Greater Brighton Economic Board (GBEB), Brighton & Hove City Council (BHCC) commissioned an analysis of the economic opportunities and challenges provided by energy across the Greater Brighton area, covering power, heat and transport. The scope required the following:

1) Review of existing and previous Energy Plans completed at local authority, regional and national levels including the previously commissioned Tri-LEP reports.
2) Development of a project pipeline of opportunities in the Greater Brighton Region
3) Development of a solar road map
4) More detailed analysis of solar and storage opportunities
5) Identify delivery models for supporting the development and delivery of projects in the project pipeline
6) Analyse the project pipeline including development of a scenario that would allow the Greater Brighton region to deliver against national decarbonisation targets (noting that subsequent to the commissioning of this report a number of authorities have now also declared climate emergencies)

In developing a viable approach to the energy strategy, it was decided to continue on the basis of the 5 themes described in the Tri-LEP study i.e. Energy Efficiency, Renewable Energy, Heat, Transport and Smart Energy. These would however be applied in a more local context to assess projects and categorise them in the Greater Brighton region.

In addition, the analysis needs to be based on scenarios that can deliver against national decarbonisation targets. In developing an approach the published National Grid Future Energy Scenarios were reviewed. Of the 4 scenarios used by National Grid only 2 met the national targets, i.e. 2 Degrees and Community Renewables.

The graph on the left of Figure 2—2, below describes the scenario for 2 Degrees. In summary this assumes a more centralised approach to decarbonisation through the deployment of large amounts of offshore wind, nuclear energy (SMRs) and through the decarbonisation of existing gas infrastructure through hydrogen (which increases rapidly in utilisation from about 2030). The graph on the right describes the Community Renewables scenario which has a far more decentralised approach, relying on a combination of local and central initiatives but including the focus on energy efficiency, electrification of transport and heat and significant reduction of gas for heat.

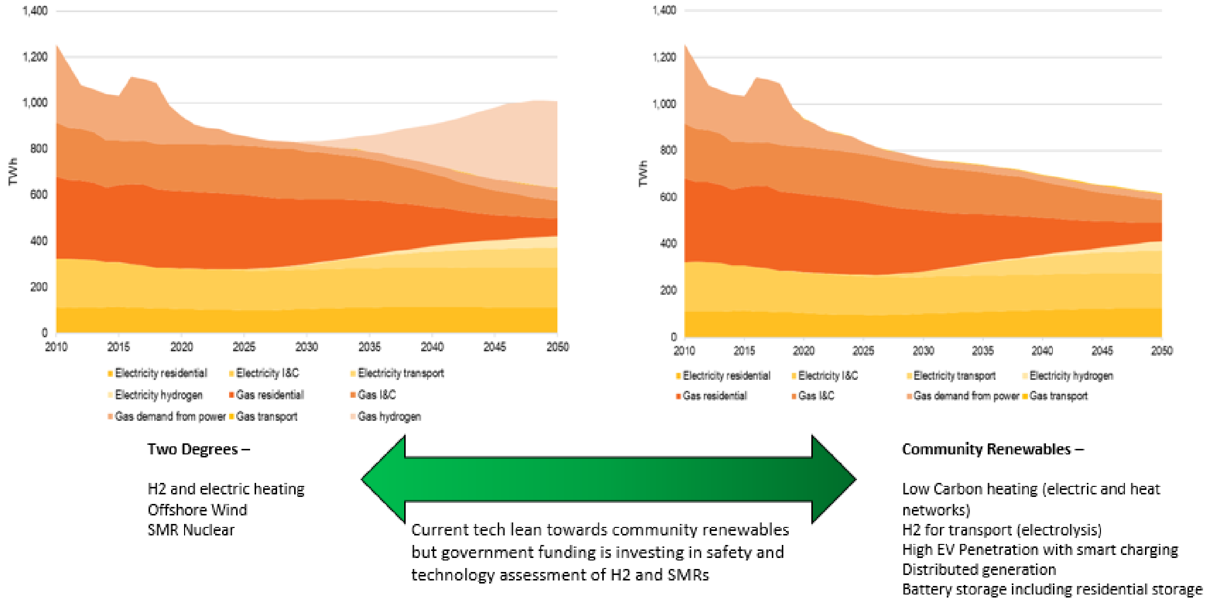

Figure 2—2 Summary of the National Grid Future Energy Scenarios.

Both approaches are considered feasible. However, it was agreed with the Greater Brighton Infrastructure Panel's Energy Subgroup that the emphasis should be placed on a project pipeline that would not only deliver against the region's carbon objectives whilst supporting local economic growth but also be a pipeline that can be enabled through direct support and influence of the local authorities in the region.

In considering this, it was felt that Community Renewables fitted far more closely with this remit i.e. to develop a portfolio of local projects that fall within the 5 themes but that can be influenced locally by local authority involvement.

2.3 Report structure

This report is made up of eight remaining sections:

3. **Approach** – details the key methods used to inform the energy plan: stakeholder engagement, GIS mapping and modelling, decarbonisation pathways analysis, and a desktop research study.
4. **Key strategy areas** – provides an overview of the suggested actions and prioritisation in Greater Brighton for each of the Tri-LEP energy strategy key areas: renewable generation, heat, transport, energy efficiency, and smart systems.
5. **Characterising the area** – this draws extensively on GIS work, exploring the renewable resource, constraints (both environmental and in terms of the energy network), heat and gas grid access, a brief summary of key support mechanisms for low carbon projects, and historic carbon emissions in the Greater Brighton region;
6. **Technology options and projects** – this gives a review of low carbon technology options (with a particular focus on heat and storage – solar power is explored in-depth in the solar road map section), it then summarises the key project opportunities and requirements for Greater Brighton.
7. **Delivery models** – this section explores project ownership options, power purchase agreement strategies and various financing options, with the latter including consideration of a Greater Brighton Energy Investment Company.

8. **Case studies** – six case studies were developed as part of this energy plan, exploring specific projects in more detail. The case studies are for a hydrogen hub at Bolney, multi-vector opportunities at Newhaven, integrated energy systems at Crawley (with a focus on heat), solar car parks at Haywards Heath train station, and feeding solar power into the railway system with the Riding Sunbeams project.
9. **Solar roadmap** – this section can stand alone as its own short report for solar power in the region. It reviews the current status of solar power in Greater Brighton, technologies, the context for solar development (including planning considerations and economic support), potential projects, SWOT analysis of general solar power approaches, and priorities and recommendations.
10. **Carbon modelling** – the final section explores how zero carbon projects in Greater Brighton contribute to the transition to a carbon neutral energy system.

3 Approach

As discussed in the introduction the project is framed within the context of the National Grid Future Energy Scenarios and the Tri-LEP South2East energy strategy. This section briefly outlines the four main methodology approaches used in this work to apply the Tri-LEP work and themes in a local context.

3.1 Stakeholder engagement

Stakeholder engagement was key to this process to identify projects, delivery models and strategies. This was done in three major ways: questionnaires, meetings and a series of workshops. We would like to take this to thank everyone who attended the meetings and workshops and answered the questionnaires – providing a huge amount of useful information.

The overall strategy was to use to questionnaires to identify key projects; workshops to discuss key themes, identify further projects and inform delivery models; and meetings to gather more detailed information about specific projects and issues. Findings and a draft report were presented to the Greater Brighton Energy Panel in order to gain feedback and ensure no key areas were missed.

3.2 GIS

GIS was used extensively to gather, interrogate, analyse and present data. With one of the deliverables from this piece of work being a compiled dataset of projects and datasets. Projects gathered during the stakeholder engagement were entered into a GIS database so they could easily be viewed, these were combined with publicly available and BuroHappold generated datasets to give a geographic overview to the Greater Brighton energy system and its context.

Base dataset examined and integrated include: resource maps, fuel poverty and Energy Performance Certificate (EPC) data, landfill sites, environmental constraints, electricity network constraints, access to the gas network, existing large-scale solar projects, major emitters in the area, site specific area assessments, and elevation models. The results of the GIS analysis are presented throughout the report.

As well as being used for mapping based exercises GIS was also used to carry out detailed solar modelling of rooftop potential. The approach and GIS tools used utilise high resolution freely available Digital Surface Models from the England and Wales LIDAR datasets. This is coupled with satellite derived typical meteorological year information available from the EU PVGIS project, to ensure site specific solar influx data. Peer reviewed toolkits (primarily UMEP and SEBE) within QGIS are then used to create fine resolution solar maps. The level of information is so detailed solar potential can be analysed at ~1m^2 resolution, this allows analysis of specific rooftops on a site. This information can then be used to inform detailed yield analysis and technology siting locations for areas identified as suitable. An example of this analysis is presented in Section 8.2.

To ensure the GIS data and outputs produced are compatible with BEIS best practice BuroHappold and a Greater Brighton representative attend a workshop bring together several different south east LAs and other key stakeholders. The aim of the workshop being that all energy mapping projects in the area conform to a common set of approaches and formats to allow them to be integrated into a centralised database. To this end all information is where possible stored in shapefile format if it is of vector type, or if it is raster is raster in a geotiff. With all data being in the British National Grid projection (EPSG:27700), aligning to the BEIS and wider UK standards.

3.3 Decarbonisation pathway analysis

The BuroHappold Sustainability team have created an in-house tool which has been applied in other Local Authority contexts to model low carbon transitions pathways. This was adapted to consider multiple Local Authorities at once and take into account key technology decisions for Greater Brighton. The modelling approach meshes together historic emission data, forecasting analysis, policies and localised project decisions to model carbon reductions form different sectors and vectors. A summary of the approach is provided below in Figure 3—1.

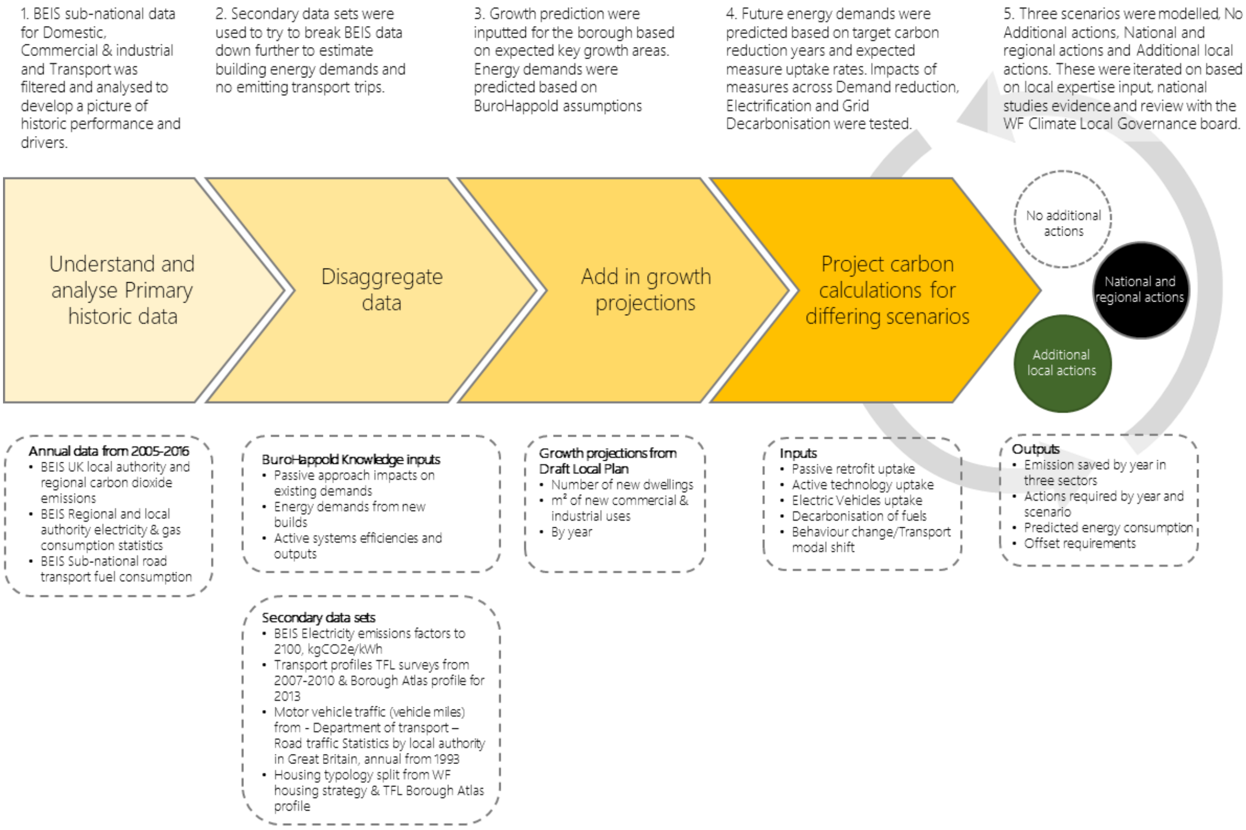

Figure 3—1 Methodology used to model and project carbon emissions in Greater Brighton.

The results of this analysis represent the final outcomes of this report, illustrating the extent to which Greater Brighton will have to act beyond what is easily realisable to achieve a net zero carbon future.

3.4 Desktop study

The desktop study included discussion of delivery models, support mechanisms, technologies, historic trends in low carbon installations in the area and potential projects. These were based on developing information provided by stakeholders in addition to traditional research approaches and BuroHappold's experience on other projects. A number of case studies were also developed as desktop studies, providing further details of the areas of interest and their economics.

4 Key strategy areas

This section provides an overarching strategy for a low carbon energy system in Greater Brighton. This is based around the key themes identified in the Tri-LEP study of renewable generation, low carbon heat, low carbon transport, energy efficiency and smart systems.

4.1 Renewable generation

Renewable generation in the context of the Greater Brighton Energy Strategy is considered as any form of distributed renewable generation source. Whilst it is appreciated there is some centralised generation in the region, i.e. an offshore wind farm, this is not considered applicable within the scenarios focussed on given the need for large scale investment programmes and its connections to the transmission system where the renewable contribution is therefore considered as a national contribution rather than a local contribution to decarbonisation.

The primary focus of the project has been the development of a solar roadmap which will underpin a local strategy to maximise solar yield in the region. The accompanying solar roadmap and GIS identify the current solar generation in the region and the potential for increasing this further. Previous installations have been supported by feed in tariffs (FiTs) but future installations will no longer be subsidised. However, the installation cost of solar generation £/kW is approximately 20% of what it was 10 years ago and is still decreasing. This coupled with new commercial models such as power purchase agreements (PPA), community energy models and behind the meter solutions still make solar generation extremely attractive. Other aspects explored by this report include the application in connecting to significant demand centres that are now emerging including the rail system and EV charging hubs.

Solar thermal should also be considered and can be incorporated with buildings to provide further support for hot water production. This will contribute directly to reducing energy consumption of alternative heat systems and can be used in conjunction with thermal storage to provide night storage.

Onshore wind turbines provide a complementary source of renewable generation to solar and an analysis of wind yield in the region has been assessed and presented later in the report. Due to changes in planning laws instigated in recent years and the removal of subsidies the development of onshore wind nationally has stalled. However, the developing of onshore wind farms are still permitted but are now subject to more stringent local planning requirements which should be supported by the local authorities and communities at the proposed locality. Community models will be particularly relevant to the uptake of onshore wind solutions going forward unless policy changes are made. PPA agreements can provide a viable way for businesses to procure local wind generation which will then directly contribute to reducing carbon emissions in the region.

If applying the regulator's classification then grid scale electricity storage is also considered as a generation asset. Energy storage can significantly improve the operation and flexibility of systems and provide flexibility support the local distribution network which may be provide a revenue stream as a result of flexibility contracts. UKPN has recently published a number of new sites in the region that will benefit from flexibility services. The business case for energy storage applications normally considers a number of aspects including its ability to reduce network reinforcement, time shift energy, provide flexibility and arbitrage services. The size of storage units should be considered electrically in terms of its kW and kWh outputs respectively, as well as physical footprint and selection of the appropriate battery technology.

Biomass generation can also be considered under the category of renewable generation and can provide a viable way of delivering against carbon targets. Additionally, if sustainable fuel sources can be developed locally would also lead to local supply development contributing to the economy. It should be noted that as a 'green' technology biomass is controversial with some stakeholder groups referring to historic problems with performance and emissions which need to be carefully considered.

4.2 Heat

Heat accounts for approximately 30% of UK carbon emissions split roughly equally between commercial, industrial and domestic utilisation. This sector is therefore an extremely relevant component for the Greater Brighton Energy Strategy. However, it's not without its challenges. A recent report commissioned by the National Infrastructure Commission (NIC)[2] identified the need to reduce carbon contributions in the UK from space and water heating from 100 $MtCO_2$/yr, a to below10 $MtCO_2$/yr by 2050 to hit carbon targets which would come at cost of circa £250-300 bn, and potentially add an additional £300 per household to bills. The National Grid Future Energy Scenarios described earlier discuss 2 broad approaches to decarbonisation of heat. The 2 Degrees scenario assumes decarbonisation of the gas grid that would see a transition from current natural gas to hydrogen and the emergence of a corresponding hydrogen economy. However, it also shows this scenario, only begin to take affect from circa 2030 as infrastructure and safety management systems are implemented to allow this to happen. This scenario would allow utilisation of the existing gas infrastructure and replace traditional gas boilers with hydrogen boilers and has the additional benefit of ensuring the consumer experience of heating is retained very similar to the current system, which in theory will accelerate uptake. In addition, utilisation of the gas transmission and distribution system will negate the need for significant reinforcement of the electricity system. However, for the purposes of the Greater Brighton Energy Strategy the focus has been on implementation of the alternative Community Renewables scenario, which predominantly sees heat being decarbonised through the use of a number of measures including building retrofit, electrification of heat and heat networks. As indicated earlier this scenario is selected because it supports the implementation of projects in the short and medium term, which can be influenced by the local authorities. It should be noted that gas networks can still play a key part in the transition through hybrid heat schemes which utilise gas boosting to support heat pumps at cold periods and when there is an additional heat requirement.

Electrification of heat is to some degree supported by current government subsides such as Renewable Heat Incentive and the Energy Company Obligation. Heat networks are supported by the Heat Network Delivery Network (HNDU) and Heat Networks Investment Project (HNIP). It should be noted that all of the above subsidy schemes are due to end within the next 2-3 years and it is not currently known whether replacement schemes will be implemented and if they are, what the terms will be.

Scheme implementation and develop requires a number of considerations including the need to undertake heat masterplans, identify and segment property types and develop appropriate uptake schemes. For example, urban dense areas may lend themselves well to the deployment of heat networks especially where there are good heat anchor points in the area. Ground source heat pumps (GSHPs) are more efficient than Air Source Heat Pumps (ASHPs) and can be used on a single property with adequate land or incorporated into a 5th generation (5G) heat network system which could also utilise waste heat and geothermal sources. Special consideration needs to be given to off gas grid properties in the region that cannot use a hybrid system and where heat pump performance may be limited by factors such as house architype and the inability to undertake deep retrofits.

[2] https://www.nic.org.uk/wp-content/uploads/Element-Energy-and-E4techCost-analysis-of-future-heat-infrastructure-Final.pdf

ECO has been used successfully by local authorities already in the region to install air source heat pumps and insulation into a number of properties. The performance and utilisation of these systems should evaluated and learning incorporated into new projects.

Installation of schemes can be invasive from consumer perspective and therefore careful consideration is needed in how to approach consumer groups to engage with them and transition them to new system approaches.

Electrification of heat as discussed above will lead to significant reinforcement requirements on the local electricity distribution system, which can also delay update of systems. Therefore, a systems planning approach is key to mitigating this including the integration with smart control and management systems, application of community heat models, incorporation of hybrid systems and taking an area planning approach including working closely with the distribution network operators (gas and electricity).

Other considerations to reduce electrical infrastructure would include incorporating solar thermal storage systems the integration of thermal storage systems, transitioning to low temperature heat networks and incorporating waste heat wherever feasible into heat distribution systems.

4.3 Transport

The transport sector as a whole contributes to 32% of the UK's carbon emissions. The decarbonisation of this sector is therefore significant in contributing to both national and local targets. Currently 70% of transport emissions are from cars and vans, 21% are from heavy transport and 3% from trains with the remaining coming from shipping and aviation. Recent developments in central government policy include the decision to ban the sale of fossil fuelled cars and light vans by 2040 with a view of tackling the greater portion of these emissions. Reaction from the automotive industry has been significant with a number of new vehicle options available in show rooms and consumer familiarity and uptake now taking hold. Currently one in every 47 cars registered is plug in and this proportion is set to rise significantly over the next few years. Furthermore, local emissions policies are being developed in many areas which will further accelerate the uptake of electric vehicles in urban areas where these are applied. Encouraging modal shift and a greater level of active travel will help to contribute to a reduction in the energy demand arising from transport, thereby reducing associated carbon emissions.

4.3.1 Electric transport

The planning and distribution of EV charging points is critical to enabling the uptake of EVs in the region. Whilst there are options currently for both plug in hybrid electric vehicles (PHEVs) and pure battery electric vehicles (BEVs) an e-mobility strategy should consider the facilities provided for BEVs which do not have the ability to fall back on an engine.

When considering an EV strategy and location of charging it is imperative that the mobility model for the region be considered that not only takes into consideration current mobility but also future mobility and the aspirations of the region. This could for example include a focus on increased utilisation of public transport, cycling and scooter mobility models.

The location and utilisation of charging stations should also be considered with options including home charging, street charging, work place charging and public charging. All of these will lead to different utilisation considerations which will then translate into energy infrastructure requirements for the region. Examples being that those with home charging will be less likely to use public charging and will rely on single-phase fast chargers, which will often be used at night whilst public charging hubs are likely to be tailored to 3 phase DC rapid charging units which can be utilised often at peak times following similar patterns to current fuelling stations.

Another consideration from a mobility planning perspective is the likely dispersion of traditional fuelling stations as fossil fuel usage drops which could impact low-income families and small business who cannot afford to transition without a form of financial support.

A technology appraisal is recommended when considering infrastructure choices to include the selection of charging unit type and retail model to be utilised. For public transport, options such as taxis and buses very different charging patterns are to be considered which should be linked to the utilisation of these transport options e.g. whether charging at depots or key stops are required. Furthermore, there are new developments such as induction charging and vehicle to grid charging options which could be further incorporated into infrastructure.

4.3.2 Smart control and management

Consideration is also needed in terms of smart control and management of charging infrastructure which has many benefits including significantly reducing peak energy consumption (thus reducing CAPEX of infrastructure) and utilising renewable generation more effectively. Figure 4—1 taken from NG FES shows that for EV uptake the potential increase in electricity consumption and corresponding infrastructure support could be significant (many GW nationally) but that though smart control and management this can be considerably reduced. This approach will also be reflected in terms of local infrastructure requirements which if not addressed could provide a significant barrier to EV infrastructure uptake in the region.

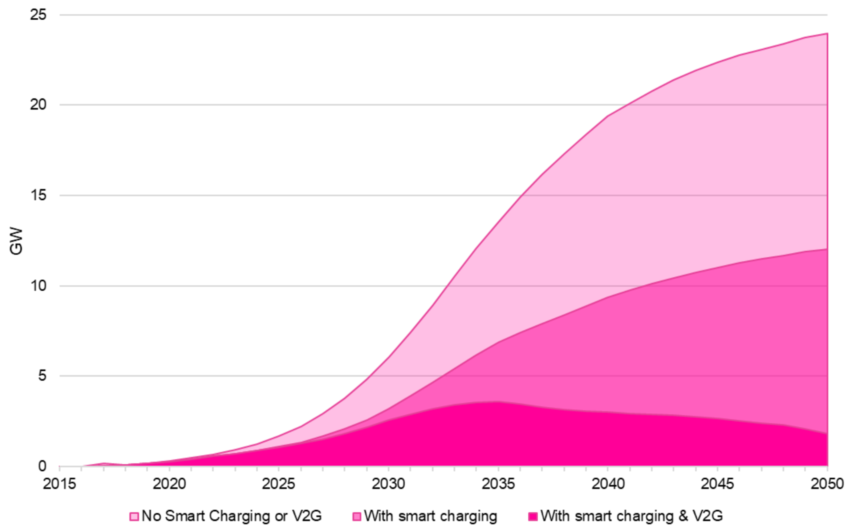

Figure 4—1 National Grid Future Energy Scenarios – Community Renewables electric vehicle demand.

4.3.3 Hydrogen Transport

An alternative approach to decarbonising transport referenced in the National Grid Community Renewables scenario is the utilisation of hydrogen. Whilst hydrogen fuel cell cars are available on the market now the main focus is on the decarbonisation of heavy transport which would include for example lorries, heavy vans and buses. Current technologies make electrification of these transport modes unsuitable for any significant mileages; whilst the utilisation of hydrogen is considered on par with a normal fuelling experience.

This approach represents a key opportunity for the Greater Brighton region in demonstrating how its transport hubs can be decarbonised through the application of these new technologies. Whilst distributing hydrogen through the gas system is not considered in this report the production and distribution utilising electrolysis is. The recent developments in containerised electrolysis systems mean that hydrogen can be manufactured and stored on the site of use, i.e. fuelling stations.

The production of hydrogen requires water and power. The price point of hydrogen can be considerably reduced by the integration of electrolysis plant with locally supplied renewable energy and a water strategy with the target price point to be competitive with diesel fuel to encourage uptake. It should be noted that at this time there is no policy direction targeted at this segment unlike light vehicles, relying on commercial models to develop interest and uptake. It is known that in the region, Gatwick Airport has procured such a system and therefore good insight could be provided into the regional strategy from the airport (https://www.h2-view.com/story/new-hydrogen-station-opens-at-gatwick-airport/).

It should be noted that regulation will need to be reviewed to support the development of hydrogen as transport fuel. This also applies to its application for heating, where this perhaps even more significant.

4.4 Energy efficiency

Basing the approach to developing a viable project pipeline on a Community Renewables Approach places a strong emphasis on reducing overall energy consumption as compared to historic figures. The National Grid FES shows an overall reduction in energy consumption of approximately 500 TWh compared to 2010 figures in the community scenario. This 'efficiency' improvement in national energy consumption can be delivered in a number of ways, with some examples below:

4.4.1 Fabric Retrofits and Building Efficiency (domestic)

Approximately 10% of the UK's heat load is for domestic energy. When appraising its Green Deal the UK government identified building retrofit as a key strategy in decarbonisation with some 14 million homes estimated as viable with an estimated annual CO_2 saving of 1.5 tonnes per household annually. The Greater Brighton region has like the rest of the UK has a considerable variance in housing stock in terms of age, archetype and condition. Improving the quality of housing stock through energy efficiency measures will ensure overall reduction of energy and ensuring performance improvement for installation of low carbon heat solutions such as heat pumps. Applicability of such measures can include fabric improvements such as loft insulation, solid wall or cavity wall installation and double glazing. In Greater Brighton the Warmer Sussex Group is currently reviewing EPC data to identify target areas across Sussex for promoting energy efficiency amongst home owners, which could result in substantial efficiency gains.

Efficiencies have also been proven with the incorporation of new smart thermostats and control systems which can reduce energy usage in properties by up to 12%. An EU project (INTELLIGENT METERING) identified more advanced intelligent energy management systems are capable of saving up to 30% of the energy used – although 20-25% is generally considered more achievable.

Segmentation of consumer groups and property owners is required when approaching fabric retrofit. For example, council owned property will allow more rapid intervention by the local authority whilst private owned and private landlord require very different approaches. Private owned will typically be focussed on cost and disruption of the intervention. For private landlords there may be less motivation although recent legal changes mean that EPC ratings of properties must be a minimum of E and this may become more stringent in the future. Tenants can currently apply for measures based on means testing but take up is often low which can be down to a lack of education and knowledge in this area. New builds will typically perform much better due to new building regulations and the government's Each Home Counts initiative is also seeking to reinforce this through the application of new certification and standards.

Similar measures can be used with industry to reduce commercial energy utilisation; however, the approach is clearly different with a very varied range of buildings and ownership models, integration with building management systems and negotiations with landlords often required.

4.4.2 Heat Pumps

Replacing traditional boilers with heat pumps will deliver multiple benefits and from an energy efficiency perspective the achieved coefficient of performance of the system (COP) which in simple terms for an electric heat system is the ratio of heat energy delivered vs the electrical energy used to power the pump. For air source heat pumps a typical installation may achieve a COP of up to 3 whilst a GSHP can be up to 4 (although it should be noted that many installations in reality achieve lower and having a good quality installation is critical. These compares to direct electric heating which has a COP of 1. This means that whilst overall electricity demand would increase significantly, overall energy demand will drop far more rapidly due to the efficiencies these systems bring.

4.4.3 Electric Vehicles

Electric vehicles can deliver multiple benefits including both environmental and health benefits due to lowering emissions. In addition, it is important to consider the round-trip efficiency of electric vehicles in comparison to fossil fuel vehicles. A gallon of gasoline holds approximately 33 kWh of energy and in an average petrol car would deliver approximately a 40 mile range i.e. 1.2 miles/kWh. An average electric car will do approximately 120 miles on a 40kWh battery which equates to 3 miles/kWh. Therefore, in simple terms switching to an EV and driving the same miles would reduce overall energy consumption by approximately a 3rd. Furthermore, the cost of producing electrical energy from renewables is marginal and compared to the production costs and emissions of fossil fuel production places further emphasis on the considerable overall savings that can be made at a national level. Local integration of renewables into vehicle charging infrastructure is a further consideration discussed further in this report which would directly contribute to Greater Brighton agenda.

4.5 Smart Systems

Smart Energy is concerned with the integration and enhancement of systems operations through digital solutions. It has not been considered a discrete area in itself for the project pipeline because by its very nature a smart energy strategy is about the integration of infrastructure. However, this should not detract for the significant value placed on developing a coherent smart energy strategy for the region which will be crucial in delivering against carbon targets and improving energy efficiency.

Smart Energy can be considered in terms of the full energy supply chain; i.e. from transmission to behind the meter and will incorporate many systems including a smart energy grid, smart buildings, smart meters and smart EV charging.

Figure 4—2 shows the migration of the energy system from a centralised to a decentralised system respectively. Originally generation was in the form of large power stations transmitting power over a transmission system then a distribution system to consumers. Over recent years this has changed to a more distributed and integrated system whereby smaller renewable generation has been connected at distribution levels (lower voltages). This pattern is continuing which without intelligent control and management will cause issues for the operation and management of the system which translate to the consumer in terms of reduced resilience and power quality. However, with the development and integration of smart management systems this will allow the transition to a more dynamic, robust system incorporating far more renewable generation as well as enabling the transition of energy consumption to low carbon options such as low carbon heat and transport; which otherwise will not be possible without considerable expense on network reinforcement.

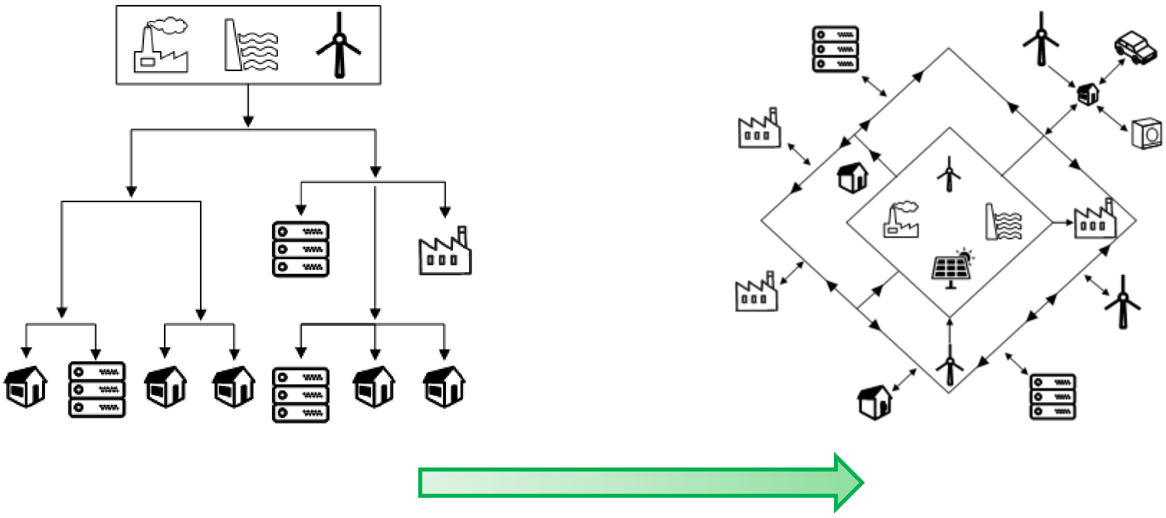

Figure 4—2 The shift from a centralised to decentralised energy system.

The electricity Distribution Network Operators (DNOs) are now migrating to Distribution Systems Operators (DSOs) under changes in the regulatory framework, which will mean their networks, will become smarter and more integrated and they will become more responsible systems operations of their network under new operating licences. This requires more integration with sensors and intelligence but has the benefit of providing better operation and control of distributed energy resources (DERs) in the region such as solar PV, energy storage heat control and EV charging management.

There is currently a central government initiative to install smart meters in all homes which will facilitate transitioning domestic users to learning more about their energy consumption and in later generation of meters would allow control of management of in home systems. Additionally, there are now a number of third party systems, which can provide intelligent home control, and thermostats to reduce consumption with typical results showing that up to a 10% reduction in energy consumption can be achieved.

For major transitions in transport and heat, the use of smart systems will be critical in enabling uptake and reducing reinforcement costs (and delays) of the electricity distribution system.

Figure 4—1 (National Grid Transport demand figure used in Transport section) shows that on a national basis without smart energy management the uptake of electric vehicles could incur some 24 GW of additional generation (the equivalent of 13 new Hinckley power stations!). In addition, the reinforcement costs of the power networks to deliver this demand would be significant running into many billions of pounds. However, the analysis also shows this figure can be reduced significantly to approximately 10% of this figure with the incorporation of smart vehicle charging infrastructure.

The control and management of DERs will also further facilitate the transition to a low carbon economy. Examples will include the use of behind the meter systems allowing consumers to utilise their own renewable energy generated local, whilst energy storage solutions mean that energy can be stored and used at different times when needed. Please refer to the energy storage section and case studies for examples.

Smart energy management is not just limited to managing demand through direct control of assets but also using digital systems for the retail management allowing multiple tariffs and payment modes. This can also be further used to drive consumer behaviour where consumers select how, when and where to consume energy depending on the service offering. This can be employed in any context e.g. home energy consumption and EV charging. Such systems will further reduce demand and allow peak shaving whilst addressing aspects such as fuel poverty where consumers have the option of selecting low cost energy tariffs based on the cost of energy.

5 Characterising the area

This section draws extensively on GIS work, exploring the renewable resource, constraints (both environmental and in terms of the energy network), heat and gas grid access, a brief summary of key support mechanisms for low carbon projects, and historic carbon emissions in the Greater Brighton region.

5.1 Renewable resource

This section provides an overview of the two key renewable resources in the Greater Brighton area – onshore wind and solar power. Consideration was also given to the inclusion of biomass and hydro power. The sustainable biomass supply chain is discussed in Section 6.6, however, it is seen to have limited application so not included here. In the case of hydro power there are some run of river opportunities, some of which on the Ouse have been explored by OVESCO. These and other opportunities in the area are seen as small scale and few in number, so not fitting into a wider energy plan for Greater Brighton; however, they could still be significant in a local context (such as Barcombe).

5.1.1 Solar

In Greater Brighton the raw solar resource, usually measured by Global Horizontal Irradiance, is highest on the south coast and decreases slightly to the north; this is shown in Figure 5—1.

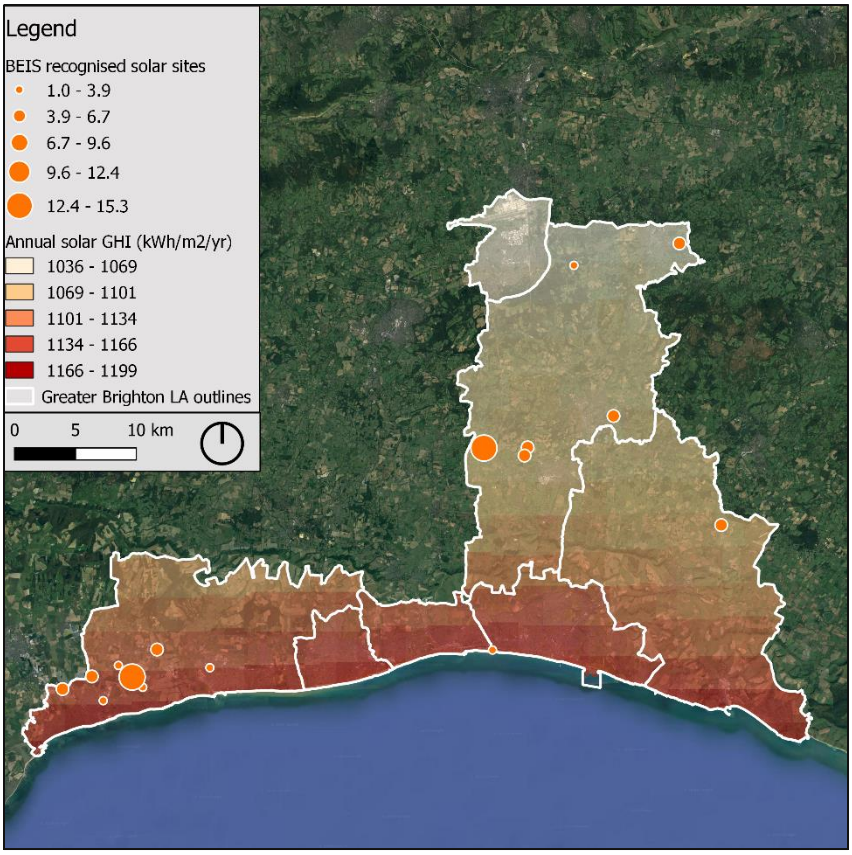

Figure 5—1 Solar resource in the Greater Brighton area. Solar data was taken from the International Renewable Energy Agency https://irena.masdar.ac.ae/gallery/.

The raw resource is broadly similar across Greater Brighton – with a suitability located array in Crawley likely to generate very similar levels of electricity as one in Brighton over the course of a year. Very local factors tend to make a large difference to solar power, such as overshadowing from trees or if it is roof mounted angle and aspect. In some situations topographic shading can be significant but the scale of the Downs. Furthermore, any areas which are likely to be shadowed by the Downs are unlikely to be developed due to technical challenges or environmental and planning constraints, such as the National Park status.

Further detail of the solar resource in Greater Brighton is provided in Section 9.

5.1.2 Wind

The wind resource is reasonable in Greater Brighton, the largest resource is along the top of Downs (which will not be developed at scale due to the visual impact in the National Park) and along the coast (see Figure 5—2).

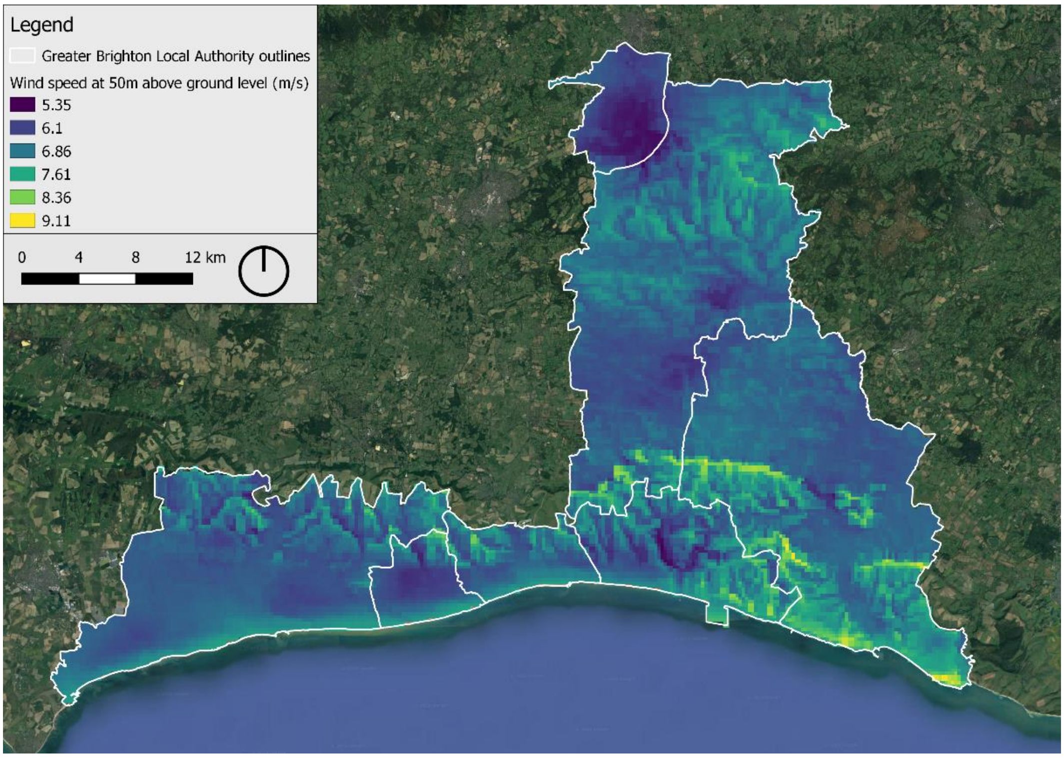

Figure 5—2 Annual average wind speed at the likely height for wind turbines (50m) in Greater Brighton. Data is from DTU's Global Wind Atlas.

Wind can compliment solar power well, with output generally being higher in winter months. This also matches demand patterns, where electricity demand is greater in winter – this relationship will be exacerbated with electrification of heat.

Local site assessments will be required but from a resource perspective there are opportunities for financially viable onshore wind projects in Greater Brighton. However, this needs to be considered within a wider planning context and consideration of appropriate scale for developments – this is done in 6.1.1.

5.2 Constraints

Constraints are considered in two main contexts environmental (explored in Section 5.2.1) and network (discussed in Section 5.2.2).

5.2.1 Environmental

Environmental constraints help define either where projects can't be developed or where although development is possible achieving consent may be more challenging. The first kind of environmental constraint examined here is topography. If an area is north facing or on a steep slope it will not be as well suited to ground mounted solar as flat areas. Whilst for onshore wind elevated ridgelines present the best resource but are less likely to achieve planning permissions due to an accentuated visual impact. A map showing the topography of Greater Brighton is provided in Figure 5—3.

Figure 5—3 Topography of the Greater Brighton region.

As topographically makes sense the flattest area, Arun, is the most dominated by large solar. It should be noted that is all due to strong local political support and that the wold to the north of the hilly South Downs ridge is also a large swathe of suitable land for large scale solar. Except for the South Downs the topography of Greater Brighton does not cause a major constraint for low carbon development. Of more significance are environmental and constraints, displayed in Figure 5—4.

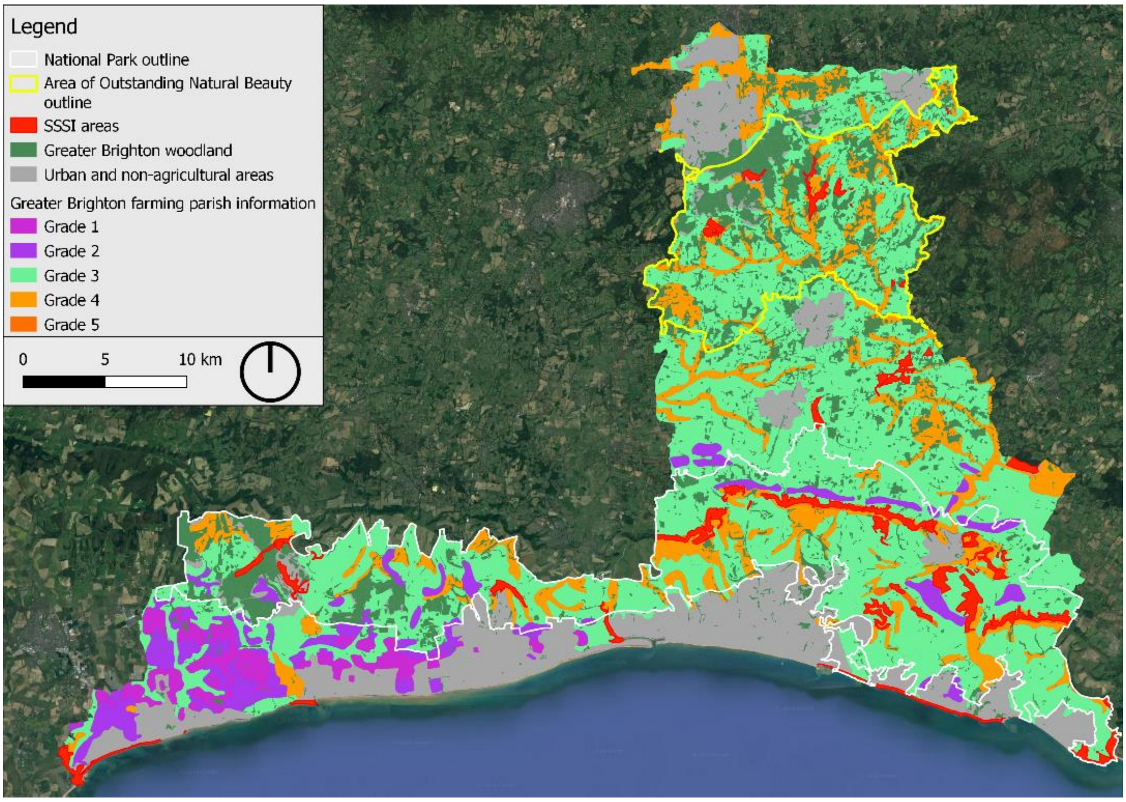

Figure 5—4 Key environmental and land use information. Map is made combining EU Corine data and various UK Government data sources.

In summary the areas light green or orange are most suited to large footprint low carbon technology solutions. The National Park outlined in white and AONB in yellow both represent areas where planning permission may be harder to achieve on large scale projects but generally align with wider national policy. In terms of legislative rather than conflict in land use the most significant areas are the SSSIs marked in red. In summary, whilst there are quite a higher number of constraints, at a regional scale there are plenty of areas suited to large scale developments, with constraints generally being more localised. For most projects identified in this work, e.g. heat networks and rooftop solar, the constraints in Figure 5—4 are either not applicable due to location or would be considered permitted developments.

5.2.2 Network

Understanding where the electricity network is constrained can help inform the potential to directly feed large scale renewable generation into the grid and identify opportunities for more novel projects providing flexibility and storage. Primary substation data is available from DNOs which provides an indication of whether networks have a constrained – if they are it can infer a lack of capacity either for additional generation, or demand, or both; these data are collated in Figure 5—5.

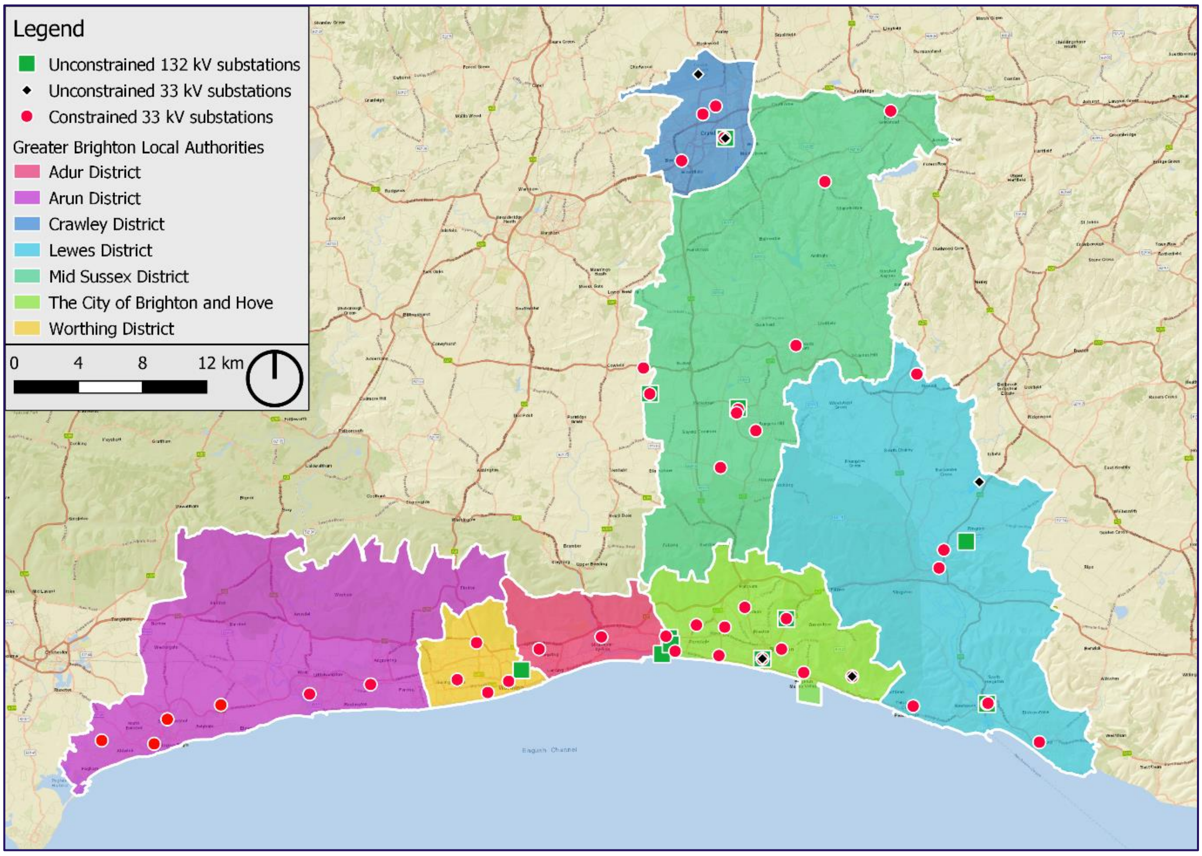

Figure 5—5 Map of primary substations in Greater Brighton and indication of whether they are constrained.

As can be seen in Figure 5—5 the majority of primary substations are constrained in the Greater Brighton region. Due to data quality all constraints are bundled, only two are flagged directly as being constrained in terms of adding more generation (however, higher quality data would be needed to assess the validity of this). The most common constraint listed is the "Transformer Thermal Rating", which is not very precise to inform a strategy. Personal communication with UKPN suggests constraint issues are unlikely to be substantial at 33kV but can, and will, be more widespread at 11kV/LV as we transition to heat electrification in particular. What is shown is that the higher voltage 132kV network is not stressed in the area, the issues being at 33kV and to a large extent at 11kV and LV creates greater challenges, as it is lower voltage levels where stresses from heat and transport electrification and distributed generation occur; as the transition in Greater Brighton towards zero carbon is not driven by large scale industrial consumers[3]. This does, however, present an opportunity, with the high level of constraint making distributed storage and coupling onsite generation and utilisation more important than in high capacity networks. Through a strategic islanding approach (this is developed in the context of a rural off gas grid network in Section 8.3) reinforcement costs could be substantially reduced.

Currently companies and consumers can provide flexibility by using the Piclo service, which identifies areas on the distribution network that have the most significant constraints. Interested parties can bid to supply flexibility through the Piclo scheme, avoiding the need for costly reinforcement. In Greater Brighton there are three Piclo areas that fall at least partially within Greater Brighton, these are illustrated in Figure 5—6.

[3] Analysis was carried out of the largest greenhouse gas emitters in Greater Brighton and as expected the biggest point emitters were shown to be relatively small compared to those areas where large scale heavy industry is more dominant.

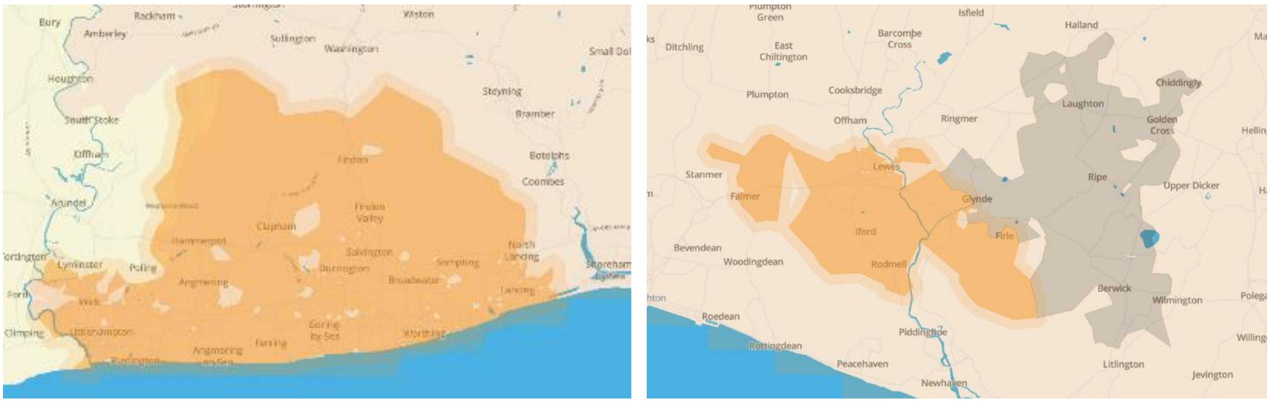

Figure 5—6 The three Piclo areas in the Greater Brighton region. The image on the left shows the Worthing Grid A area in orange. The image on the left shows two constraint areas, Lewes Central in orange and Ripe in grey. The images are taken from https://picloflex.com/dashboard?competition=nyEElyZ and are on different scales.

Piclo is seen in this Energy Plan as a useful intermediate step, reducing the need for reinforcement, however, with the widespread electrification of heat reinforcement will be required. This is demonstrated in UK energy system scenarios (such as the Energy System Catapult's Future Network Transition Analysis). The flexibility approaches encouraged by Piclo will be useful to implement to keep these reinforcement costs down.

It is suggested these Piclo areas will make a useful area to consider projects, in terms of integrated storage and generation solutions and demand flexibility. These constraint areas are discussed further as key opportunity area in Section 6.6.

5.3 Heat and gas grid access

Heat is considered the most complexed area to decarbonise. This section provides insight into the geographic issues with heat decarbonisation and progress and opportunities for decarbonisation in Greater Brighton.

Heat networks are a central government priority area to enable heat decarbonisation and is a key project area identified in this energy plan. There are multiple existing heat and heat network projects in Greater Brighton, the location of these compiled from stakeholder feedback and BuroHappold developed datasets are provided in Figure 5—7.

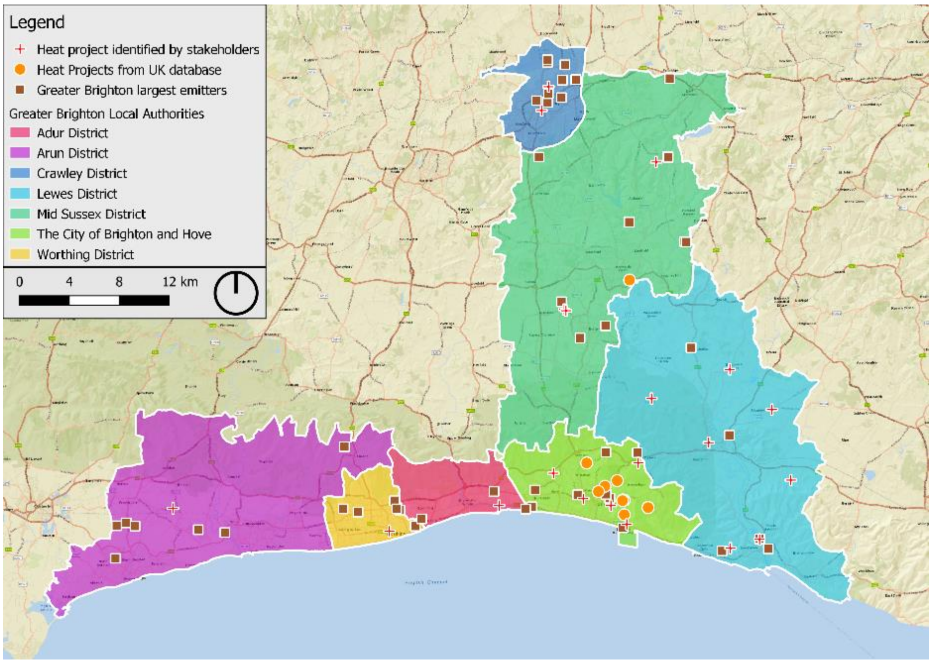

Figure 5—7 Map of heat networks and heat network opportunities. The projects identified by stakeholder cover a variety of projects from installation to opportunities.

Unsurprisingly given population densities and scale Brighton and Hove have the highest number of heat projects. Crawley has two reasonably far progressed heat network studies; the large emitters point data indicates there could be substantial waste heat available in Crawley – which could be integrated into the networks design to improve the financial viability and green credentials. In general, the large carbon emitters show there is substantial opportunity for waste heat in Greater Brighton, this is identified as a key project and discussed in Section 6.6.

Understanding building efficiency is fundamental to understanding the heat demand of an area. Greater Brighton reflects many of the wider UK trends in terms of building efficiency, with Display Energy Certificate and Energy Performance Certificate (EPC) showing poor efficiencies. A summary of EPC data is provided in Figure 5—8, this focus on domestic properties is due to the greater challenge in addressing efficiency issues to the higher number of buildings.

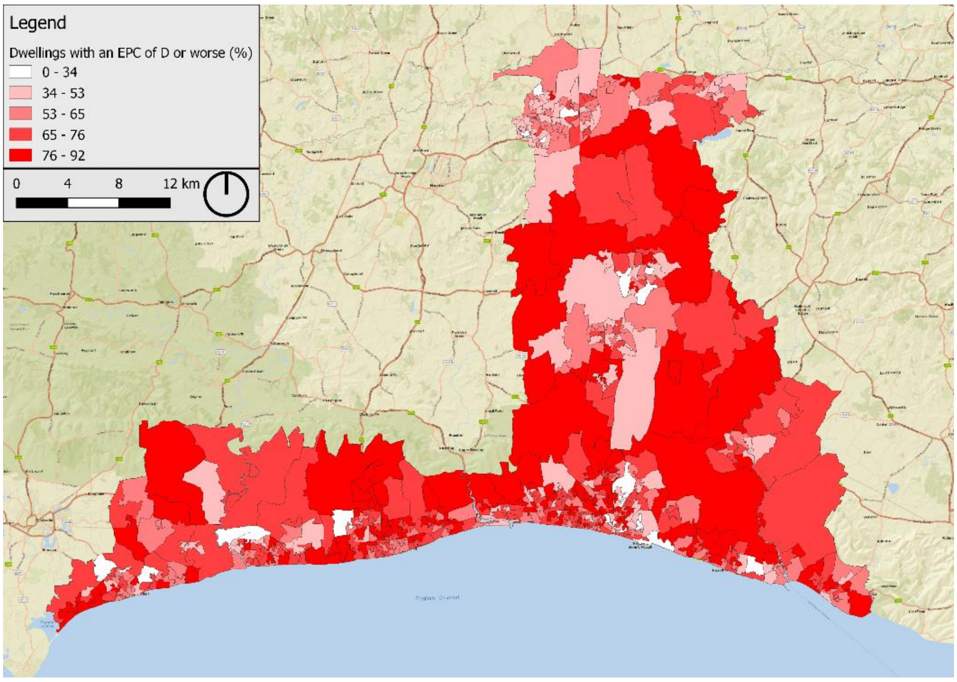

Figure 5—8 Examination of domestic energy efficiency in Greater Brighton, using EPC data.

The majority of housing stock in Greater Brighton does not achieve an EPC rating of C. Much of this stock is going to be retained into the 2050, meaning even if all new builds have an EPC rating of A the relative improvement to carbon emissions will be minimal. The advantages of new housing stock are shown around Haywards Heath, which has seen substantial growth in recent years - due to increased desirability as a commuter town.

Currently the UK's and Greater Brighton's heat demand is dominated by natural gas. Not all of Greater Brighton is connected to the gas network, which generally means higher carbon oil boilers are used – particularly in rural areas. An indication of areas where properties are connected to the gas network is provided in Figure 5—9.

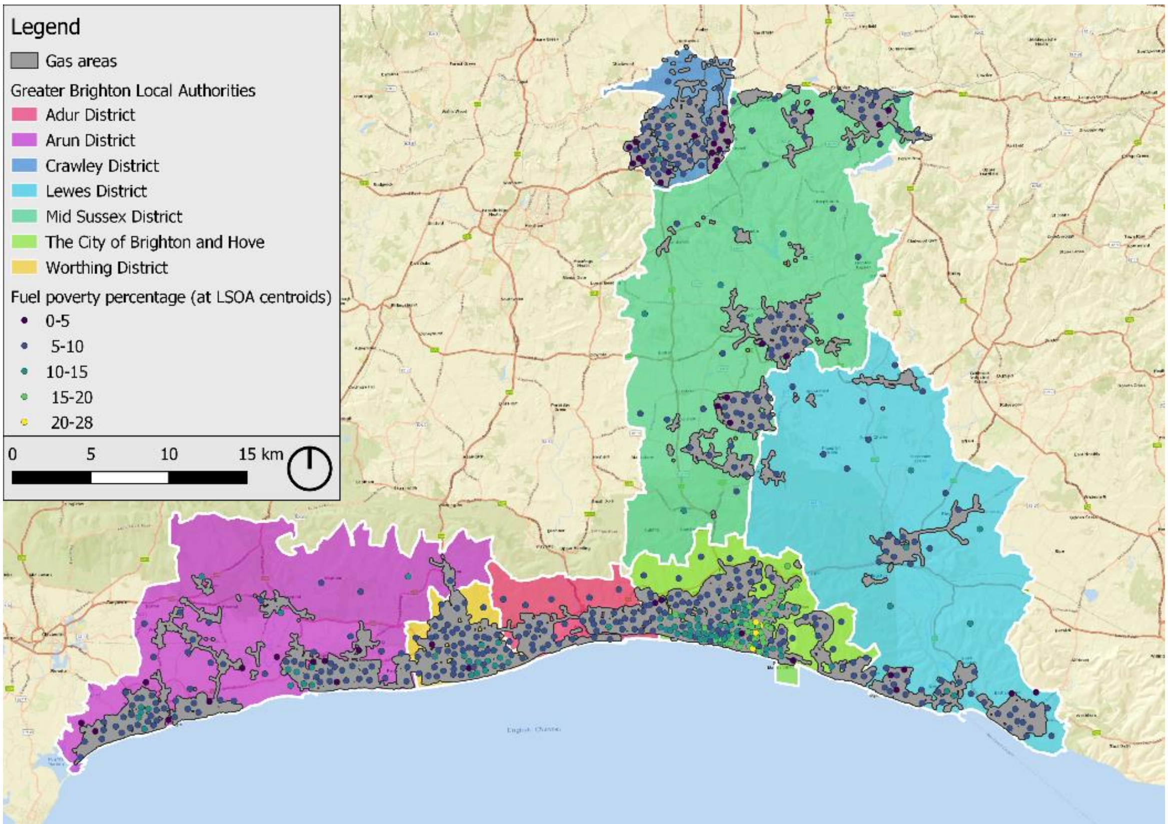

Figure 5—9 Location of gas networks in Greater Brighton and fuel poverty.

In most situations natural gas is currently the cheapest form of heat energy, however, to decarbonise there is a need to shift away from this. The UK centralised solution would be hydrogen but this would require a very long lead time in Greater Brighton. In addition to heat networks a solution which is discussed later in the reports is the partial electrification of heat through hybrid heat pumps. However, the cost of hybrid heat pumps and the currently higher unit cost for electricity (even when considering the high efficiencies of heat pump technology) means this will results in a larger cost burden for heat. This is important as there are already issues with fuel poverty in the region, with the Whitehawk area of Brighton being a clearly visible area of concern – highlighted in Figure 5—9. How to fund the low carbon transition in these already at risk on gas grid areas should be an area of focus as this plan is brought forward.

5.4 UK support mechanisms

A summary of some key support mechanisms is provided in Table 5—1, this is not a complete review but flags some of the main central government and local support schemes. A more detailed view in relation to solar power is provided in Section 9.3.1.

Table 5—1 Key support mechanisms for low carbon energy projects.

Mechanism name	Theme area	Target group	Description
LEP	All areas	All	Part of the Local Enterprise Scheme includes local energy hubs to provide support and expertise for projects. Additionally, the LEP is a potential source for significant financial and strategy support.
RCEF	Renewable Generation	Rural communities	Provides funding for feasibility and business development and feasibility studies for renewable energy projects.
Contracts for Difference	Renewable Generation	Large electricity generators	Generators bid in to receive a minimum price for electricity they generate. Currently offshore wind is dominating in terms of achieving funding for renewable generation.
Smart Export Guarantee	Renewable Generation	Small electricity generators	Acts as a replacement to the feed-in tariff, giving small generators (such as households using rooftop PV) a minimum unit price for electricity sold to the grid. At the current time the level of support looks substantially lower than through the FiT system.
Renewable Heat Incentive	Heat	All user scales	Provides a minimum price for heat generated from various low carbon heating technologies such as solar thermal and heat pumps. This can be from a household level to large heat networks.
Heat Networks Delivery Unit	Heat	Local Authorities	Provides support for heat network studies to Local Authorities for heat mapping, masterplanning, techno-economic feasibility and detailed project development.
LOCASE	All areas	Small and Medium Enterprises	Provides businesses in the South East with up to £20,000 and training and workshops. Applications include software development, machinery upgrades and building refurbishments.
Electric vehicle grant scheme	Transport	Individual consumers	Provides a £3,500 grant towards the purchase of electric vehicles.

5.5 Historic and current emissions

Historically carbon emissions have been trending downwards in Greater Brighton. This is predominately due to the decarbonisation of the electricity grid, in recent years driven by renewable growth. Carbon emissions vary between rural and urban contexts, this is shown in Figure 5—10 and Figure 5—11. The dark brown and green in these figures show electricity based carbon emissions – with the decrease in carbon being easily observable.

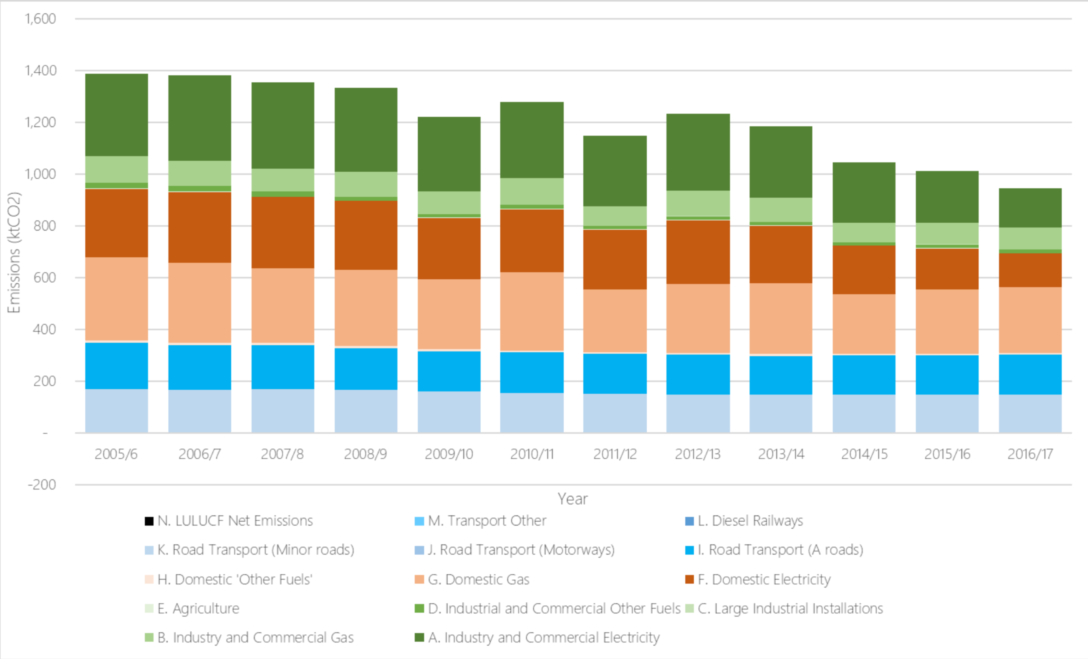

Figure 5—10 Historic carbon emissions the most urban local authority in Greater Brighton (Brighton and Hove).

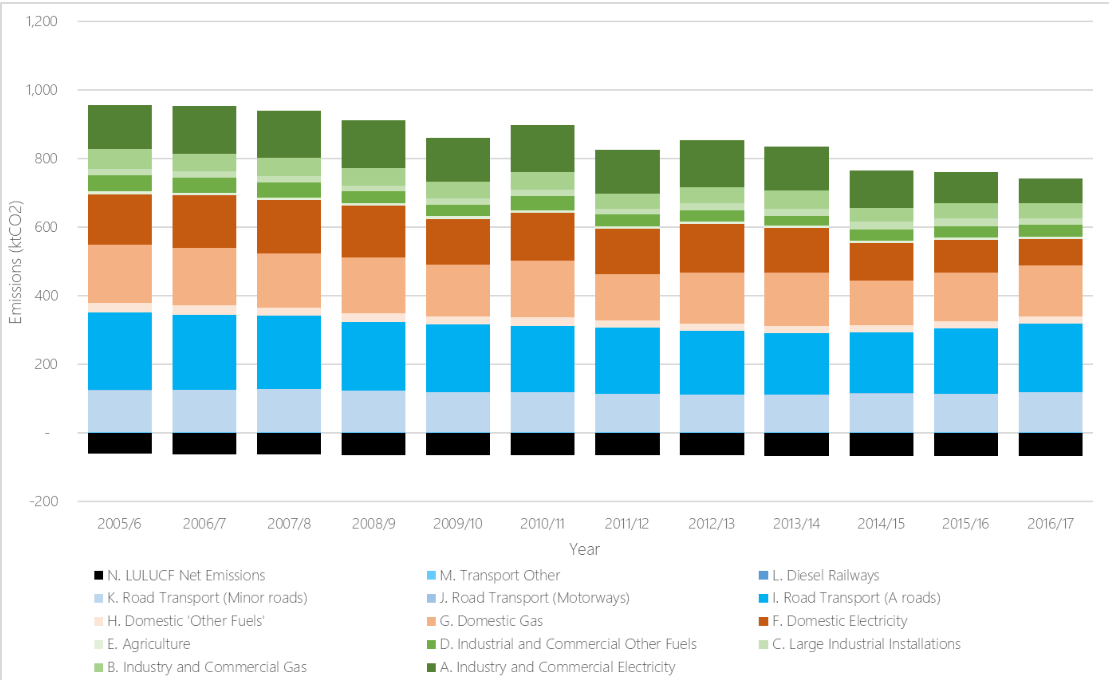

Figure 5—11 Historic carbon emissions for the most rural Local Authority in Greater Brighton (Mid Sussex).

In rural areas there is a higher share of domestic other fuels, which refers predominately to oil boilers providing heating. The high carbon intensity of oil means this is a target area within the energy strategy. Transport patterns are also different with urban areas having a more even split between major and minor roads whilst rural areas have a higher share coming from major roads, indicating journeys are longer and the areas experience more through traffic. Overall transport has remained nearly constant in both areas in terms of carbon emissions, illustrating the need to target this sector

In both urban and rural areas there have been some annual fluctuations in gas usage, driven predominately by weather phenomena - such as the particularly cold 2010/2011 winter. On average though, like transport, heat based emissions have stayed constant in the 2005-2017. Demonstrating that like transport this is important to focus upon.

The LULUCF emissions shown in Figure 5—11 are from factors like woodlands which are sequesters of carbon and so can act to improve the overall carbon balance of Greater Brighton.

For an overview of the whole of Greater Brighton's carbon emissions please see Section 9.1.

5.6 The role of business

Businesses have a significant role to play in decarbonising Greater Brighton, both in terms of their own carbon emissions and providing the supply chain to enable these transitions, these are explored below.

5.6.1 Business programmes

In addition to the previously mentioned LOCASE support programme for empowering SMEs to reduce their carbon footprint there is active research going on at Sussex University into how businesses can contribute more. This includes business models for energy innovation services, tying in strongly with the Tri-LEP focus area of smart energy.

The approach proposed by Sussex University relies on digital technology to enable businesses to take increasingly smart approaches to energy, termed as 'climbing the innovation ladder'. There are three key stages to this summarised in Figure 5—12.

Fully integrated local energy system

- Innovations built on large-scale social, economic and digital integration through new digital platforms and market mechanisms, such as flexibility auctions to deliver a more secure grid system and allow more direct interactions with the grid in real-time.
- Business models can be local but involve horizontal and vertical integration with local energy systems and the national grid.
- Innovations include exploring the role of energy aggregators in managing the energy consumption of groups of users, creating a system focused on local energy and economic needs, and investing in the built environment to create local value through retrofits or solar PV.

Local smart system integration

- Business models offer tailored innovations around connection, integration and aggregation through new digital platforms such as Smart City platforms, and customer-focused innovations, such as smart local generation tariffs.
- This work is led by local authorities, energy NGOs and intermediaries such as Regen and DNOs.

Technology-based

- The main selling points for business models at this level are usually built on use of a specific technology, such as solar PV, smart meters and storage.
- Technology-based business models are widely used by local energy groups, local authorities and businesses, and can be developed around individual buildings, such as social housing and schools.

Figure 5—12 The innovation ladder. Taken from a briefing note provided by the Science Policy Research Unit at the University of Sussex.

The first two rungs of the ladder (technology-based approaches and local smart system integration) are already technologically ready. The first rung can be based on well established business models. The second rung is in the process of generating suitable business models, such as providing flexibility in grid constrained areas (as described in the Newhaven case study).

It is this final rung of the innovation the ladder which is what would be defined as a true smart system and as noted in Figure 5—12 to enable this there is a need for new digital platforms. The expertise in Greater Brighton makes it well placed to foster development of these platforms. The energy group could help with this and if an Energy Investment Company was created, it could help bring these to market and utilise these new technologies to real world projects.

It is strongly suggested that these novel digital approaches are built into the energy strategy, to help move towards a smart system. Having active projects already enabling this provides a strong basis to build upon. This will bring economic benefits to the area which will be coupled with social benefits of smart systems, contributing to a sustainable circular economy.

There are significant value chains for large businesses working with local SMEs. This can help both supply chain and economic growth, providing social as well as economic benefits as well as decarbonisation. Some of the largest businesses in the region, notably Gatwick Airport are active in this area. This a very significant area opportunity for Greater Brighton and the wider Coast2Capital LEP area.

5.6.2 Supply chain

To help provide the skills needed to enable the energy transition could make use of the UTC at Newhaven, which is mothballed at the moment. This could act as an upskilling centre, along with local universities, colleges and adult education. There is a need to upskill and encourage new business to set up, which commitment of Local Authorities uptake and large businesses could provide confidence for (as would a centralised bulk purchase scheme and an energy investment company with a portfolio of projects to invest in). The need for this is highlighted by stakeholders observing local supplier capacity reduce with cuts to incentives. Greater Brighton has seen successful public events to encourage uptake. For example, Eco Open House (Worthing, Brighton & Lewes have run these successfully) , local electric car shows, energy fairs and grant funding required.

When considering local supply chain, broadly any strategy fits around the following

- Preservation and Growth
- Upskilling
- New development

Examples of this approach include:

5.6.2.1 Preservation & Growth

The need to preserve any existing supply chain that has been built up on the back of the current FiT for solar. A number of installations have been carried out but if not careful the local solar PV market will stall now subsidies have been removed. However, it is clear from the solar roadmap that there is huge potential to install solar PV (and thermal) with new delivery models providing funding. Consideration should therefore be given to consultation with the current supply chain on this.

Community Energy groups have played a significant role in the local supply chain and facilitating project delivery. One example presented during the workshops was from OVESCO, who helped deliver a pre-FiT and RHI microgeneration support scheme for Lewes District Council. When OVESCO took over they were able dramatically increase scheme uptake from previous levels, with the scheme (that ran under OVESCO from 2007-2011) delivering £923,000. In this presentation the role of community energy groups in providing support to customers to ensure the supply chain is functioning correctly with one example being provided where a company were offering a solar thermal system at ~2.5 times the market price. Having a set of impartial and trusted community energy groups in the region is an excellent resource to utilise for small scale customers to utilise to build trust in the supply chain.

In supply chains economies of scale means bulk purchasing of technologies can lead to substantial reductions in costs. This model is being used to help bring costs down for small scale solar, to help alleviate the impacts of the cuts and now scrapping of the FiT. The most commonly used model is the Solar Together and iChoose for scheme, which is being adopted in London, Suffolk, Manchester and Norfolk; where householders and SMEs register their interest to have solar PV installed on their roofs. With the support of Local Authorities these household projects can be pooled, allowing a lower technology purchasing price. This driving down of costs for PV can help to overcome the challenges created for the sector by the removal of the feed-in tariff. This approach of combined purchasing power could extended beyond solar from batteries to hybrid heat pumps. It would also make a useful vehicle for delivering integrated solutions such as a coupled solar PV and heat pump project – with the PV panels providing the electricity to run the heat pump.

5.6.2.2 Upskilling

The need to decarbonise heat and scale up installation of heat pumps and related work could deliver benefits for the local heat engineers, who can retrain relatively easily to be certified in the installation of these new technologies. This provides a ready-made supply chain. It was suggested by stakeholders that use could be made of the mothballed UTC@harbourside site at Newhaven as a training centre.

The existing building supply chain can be upskilled to form multi-skill teams focussed on fabric retrofit solutions for the particular building archetypes in the area. They will be familiar with the buildings and local supply of materials and can access local labour pools.

5.6.2.3 New Development

This area covers anything that is novel and requires new skills to deliver in the region; where local supply chain may not exist or exists in very small numbers. It may in reality leverage an approach of upskilling but transferring resource into other sectors. This can be facilitated through creating new jobs and supporting local businesses and academia to provide courses for study and apprenticeships. Encouraging inward investment by creating new markets will also ensure that businesses bring in these new skills. Examples would include developing innovation centres for digital services, training specialists in hydrogen gas safety to support the emerging hydrogen economy, or heat network installation specialists.

6 Technology options and projects

This section provides a review of some of the key low carbon technology options for Greater Brighton (solar power is examined in Greater Detail in the solar roadmap). Community energy was identified in this work as a key characteristic which sets Greater Brighton apart, thus attention is given to how this can help enable a low carbon transition and realise potential project. The final part of this section provides a key summary of the main project areas identified in this energy plan for Greater Brighton.

6.1.1 Wind

Onshore wind has seen very limited deployment in Greater Brighton area, with only a few developments of note being identified during the study. The first is at Shoreham Port, where being located next to the coast localised wind speeds are very high - making the relatively small wind turbines achieve very high levels of output. There is a desire at the port to expand deployment of wind technology to utilise this resource.

There are small turbines at Kings Academy Ringmer and Beechwood Hall. Although outside the Greater Brighton area there are nearby examples of wind turbines at Eastbourne and a large one at Rye called Little Cheyne Court, which provides a community benefit fund. This latter example could provide a useful basis for similar community projects, providing a basis for creating a code of best practice for similar projects.

The largest wind turbine identified in Greater Brighton is the 67m wind turbine developed by Glyndebourne Opera House, to offset their annual electricity demand (which it is currently achieving). The turbine is developed on the site of an old wind mill and falls within the South Downs National Park. Obtaining planning permission was assisted through many notable lobbyists being involved – including David Attenborough. The linking of renewables with an internationally recognised centre for arts was considered to be a major selling point for the project.

The relative success in these schemes in terms of yield but the lack of other wind projects in the area indicates development is not streamlined. For wind power to see wider deployment Local Authorities will likely need to include it in their development plans, without this notable onshore wind capacity in the area will not be realised. It was noted in the workshops that there was a general desire to see some onshore wind deployment in the area and enabling this should be pursued. It is not suggested that onshore wind should see large scale tens of MW farms like in Scotland but single or a few aggregated turbines of a similar scale to that at Glyndebourne, to be in keeping with the landscape. This will have to be done sensitively to avoid impacts to wild life and the environment, thus the National Park Authority and environment charities (like the RSPB) should be engaged early in the wind development process. This can help streamline the identification of suitable sites to take forward to development.

6.1.1.1 Offshore wind

In the UK Offshore wind is becoming increasingly mature with prices being driven down substantially. With a fall in the Contracts for Difference (CfD) strike price of 65% in four years, from ~114 £/MWh in 2015 to ~40 £/MWh in the results of 2019 CfD auction. As highlighted by the tri-LEP report Greater Brighton has a substantial offshore wind resource, this is currently being utilised by the 400 MW Rampion offshore wind farm. Rampion currently generates 1400 GWh/yr, saving 600 thousand tonnes of CO_2 a year [1]. Plans for extension are currently at the concept/early planning stage and would add a further 400 MW [1]. Increasing generation to 2800 GWh/yr saving a total 1.2 million tonnes of CO_2 a year.

Additionally, the Crown Estate Offshore Wind Leasing Round 4 has opened the South East area as a potential leasing site [2] this is displayed in the image to the right. The scale of the potential lease area means there is potential to generate the 3500 GWh annual electricity demand for the region. For example, if the indicative wind farm area illustrated in Figure 6—1 were be to developed combined with the Rampion wind farm the sea off the Greater Brighton coast would be generating over 6000 GWh per annum.

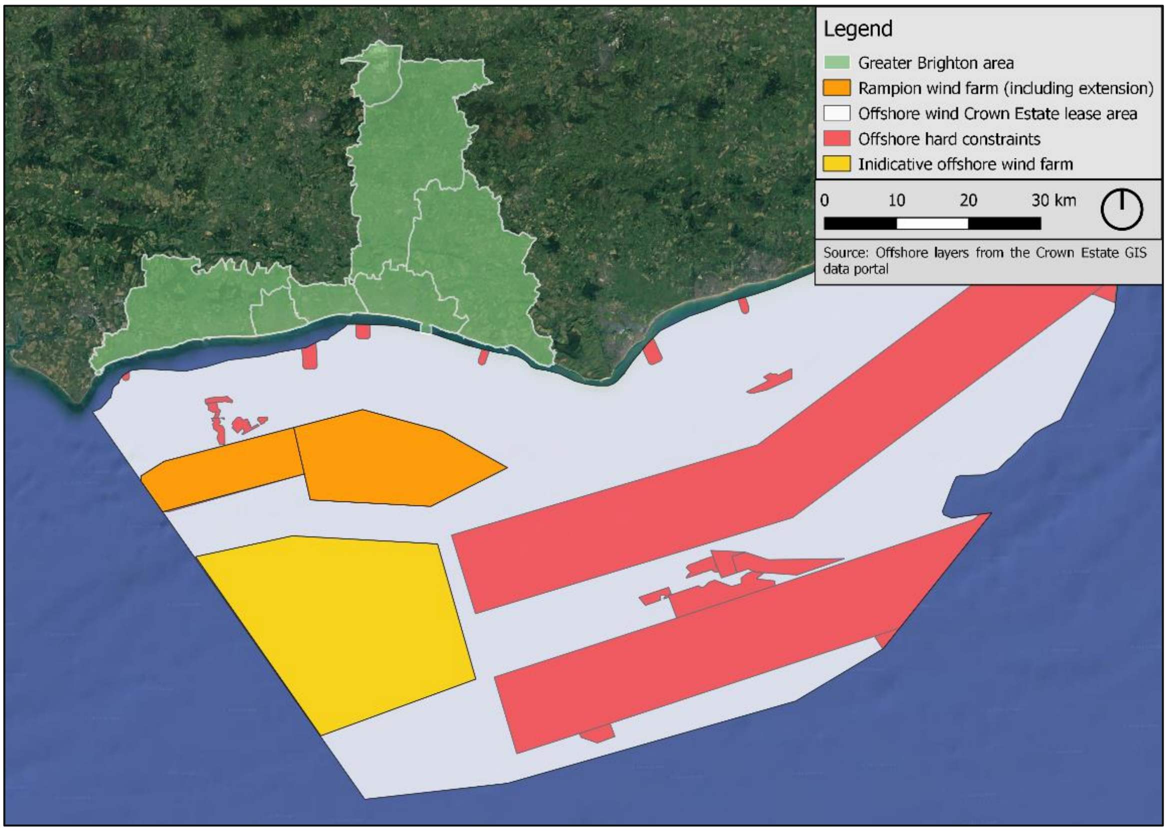

Figure 6—1 The Crown Estate South East offshore wind lease site an offshore wind farms and constraints. Rampion Wind Farm, the offshore lease area and constraints are all taken from [2]**.**

However, it is debatable the extent to which the benefit of large-scale offshore wind projects will be captured within the local area. At the current time the generation is fed directly into the national transmission system, contributing to wider electricity grid decarbonisation rather than being recognised as wholly Greater Brighton carbon savings. Furthermore, the scale of offshore wind projects means Greater Brighton has limited influence over their implementation – with national government, developers and the Crown Estate being more significant. Where the role offshore wind will be integrated into this work is for the challenge of full decarbonisation, which due to National Grid carbon content of electricity (mainly due to gas) there is a very hard to avoid emission of carbon in the region. It is the wind farms wider contribution to the grid decarbonisation, rather than a Greater Brighton energy strategy where offshore wind will be considered within this work.

For Greater Brighton to influence and internally capture the low carbon benefits of offshore wind, projects which utilise the power in a novel way should be considered. For the Rampion development there is one key example of this; where the offshore wind farm connects to the grid at the Bolney National Grid Substation there is a proposal for a 50MW battery farm, which will be used for arbitrage. There is also consideration of using the site as a hub for low carbon transport in the area, which is explored further in Section 8.1. It is also worth noting a novel project is currently being

developed in Germany, which takes this low carbon hub concept further. The project is looking to utilise offshore wind to produce hydrogen for use as an aviation fuel for a nearby airport. The Bolney substation is in a very similar situation to the German project, being located 24km from Gatwick Airport. This is seen to present a strategic opportunity for producers and users - National Grid, the Rampion Wind Farm, Gatwick and its fuel suppliers – to collaborate with a view to complementing national dialogue and policy development on sustainable aviation fuel.

6.1.2 Solar

Solar energy in the region is explored extensively in the solar roadmap (Section 8.6.1). Both solar PV and thermal technology are seen to provide significant development opportunities in the Greater Brighton area. Given the constraints for onshore wind power solar is seen as the major source of low electricity generation within the region.

6.1.3 Biomass

The local wood biomass supply chain is small but quite well established in Greater Brighton, with South East Wood Fuels being a key supplier in Greater Brighton. It provides sustainable fuel for some off-gas grid areas and also contributes to some of the biomass boilers in the area. The proposed heat network in Firle includes the use of biomass boilers. It is suggested that to support the local economy that sourcing of local sustainable biomass should be prioritised. Use of fuel in biomass boilers requires high quality control, with varying levels of moisture content and calorific content having some significant impacts on how well the technology functions. Ensuring the local supply chain meets these required standards will be useful for ensuring the viability of the supply chain for these uses.

For wood biomass to be most sustainable coppicing is an important practice. This increases the health of woodlands and can lead to increased to carbon sequestration. Examination of forestry data showed coppicing is very limited in Greater Brighton, but that sustainability is a priority of the local supply chain. To help local biomass remain sustainable in the region it is suggested that it is not used to power a widespread transition but could have an important in some localised projects.

Anaerobic digestion is highlighted in the tri-LEP report as a way to utilise waste biomass to create biogas that can be fed into the gas network to help green the gas grid. There was a scheme identified in the questionnaires in the Northern Arc development of Burgess Hill. However, progress on this seems to have stalled. It is suggested (see Table 6—5 for project details) that some anaerobic digestion could contribute to greening the gas grid.

With the exception of Southern Water, there is very limited use of anaerobic digestion in the area. Agriculture was explored as a potential feedstock for anaerobic digestion. Research indicated dairy herds are generally disappearing in Sussex and as it is waste processes from this industry that make some of the most economic agricultural feedstocks it was not considered as a priority. This is perhaps the reason for no projects appearing in the area on a national database for farm based anaerobic digestion.

6.1.4 Hydro

As mentioned in the Greater Brighton characterisation section OVESCO have carried out multiple studies of hydro on the river Ouse, showing some potential for run of river schemes. It is assumed over rivers in the area such as the Arun and Adur may also have some potential. Due to river characteristics, environmental impacts and planning permission micro and small scale hydro power (as opposed to large dam based approaches) are seen as viable. These would likely be in the order of 10-50kW and unlikely to be over 100kW. Even if 10 of the larger 50kW schemes were to be installed this would equate to 500kW. When compared to solar power, where ~300MW of additional capacity is seen as achievable, hydropower makes a small contribution. This coupled with very few suitable areas for install means it is not a major element of the overall energy plan, but it can be of value for localised solutions; such as in the case of the Barcombe case study (see Section 8.3).

6.2 Storage

Storage assets are not explicitly classified as a standalone priority theme in the Tri-LEP energy strategy, but they play an integral role in facilitating the decarbonisation efforts of clean energy projects in each of the five priority themes. In particular, they possess the necessary flexibility to maximise the intermittent energy output of the solar and potentially wind resource in the region and address grid capacity constraint issues deriving from the near-future peak electricity surges of heat and mobility electrification trends. A brief overview of applicable and available technologies is presented in Table 6—1. No storage setups or standby generation technologies involving conventional fuels are included in the analysis (e.g. diesel, LPG and power to liquids). Pumped hydroelectric energy storage (PHES) is omitted given the significant scope and size of such a site-specific storage facility, which would be assessed at a national and not regional level. Compressed air energy storage (CAES) is also omitted because it is site-specific like PHES (it requires reservoirs for storage of the compressed air medium) and is then governed by local environment constraints.

Electro-chemical storage installations, Li-ion, flow and NaS batteries above all, have grown exponentially in the last 20 years as a result of rapidly decreasing costs and performance improvements. These technologies, in particular, are able to unlock niche revenue streams in the UK electricity market because of their extremely fast response rates (under 1 s). Li-ion batteries have taken the lead, as they account for the largest share of operational installed capacity (59%) worldwide as of mid-2017 (IRENA). In the UK, their market dominance is essentially absolute as they represented over 90% of an installed capacity of just over 20 MWh in mid-2017, with the rest being mainly flow batteries. This is a result of its now established supply chain, relatively high energy and power density and low maintenance and safety requirements. The main drawback in comparison to flow batteries is its limited lifespan as a result of a higher degradation factor. Despite this, future storage project opportunities lie mainly in this battery technology.

Hydrogen electrolysis, storage and generation is on the other side a long-term option, which integrates seamlessly with variable renewable energy during periods of excess production and can be particularly effective for inter-seasonal storage and for particularly congested or constrained grid zones, by limiting the electricity flows and switching carriers by converting the excess to hydrogen (this would be considered part of a national rather than local strategy). Other long-term applications are in the transport sector, particularly for HGV fleets that have high daily mileages and require faster filling time, and in the low-carbon heat sector, where hydrogen can essentially replace natural gas as the main heat generation source and share the burden with electrified heating. The UK government has recognised the significant role and integration potential hydrogen can play in successfully achieving the transition to a leading low-carbon economy and has committed early support and funds on the technology. Electrolyser costs are expected to fall over the coming years as higher maturity levels are achieved – helping economic viability.

Both liquid air energy storage and pumped heat electricity storage are still in very early technical stages and cannot therefore be factored in yet in the region's decarbonisation pathways, but their development should be monitored in case they become applicable in future phases, particularly as large storage solutions for energy provision for extended period of time (as part of large system strategies).

Table 6—1 Summary of key storage technologies suitable for the Greater Brighton area.

Technology – and description	Pros	Cons	CAPEX - large-scale systems (£ kWh^{-1})	Cost trend
Li-ion battery storage – electrochemical battery technology where lithium ions (Li+) are exchanged between the anode and cathode.	• Modular, low maintenance system • Simple and clean • Less up front cost than Flow Batteries • Relatively high energy density	• Limited lifespan (~10 years) • High degradation factor	230 - 440	Costs expected to reduce by up to 36% by 2021 and 60% by 2030.
Flow batteries - Electrochemical cell where ion exchange occurs across a membrane separating two chemical solutions.	• Can be used like a fuel cell or like a rechargeable battery • Near unlimited longevity, no degradation in capacity; lifespan greater than lithium ion batteries (~ 20 years)	• Emerging technology • Lower energy density than Li-ion	210 – 580	Costs expected to reduce by up 19-28% by 2021 to 66% by 2030.
Sodium sulphur (NaS) batteries - The active materials in a NaS battery are molten sulphur as the positive electrode and molten sodium as the negative.	• High efficiency (although typically lower than Li-ion) • High power/energy density • Suitable for applications with daily cycling	• Operate at high temperatures (typically >300 ºC) • Use toxic materials	330 - 970	Costs expected to reduce by up to 37% by 2021 and up to 60% by 2030.
Hydrogen electrolysis and storage - Hydrogen can be produced by solar or wind powered electrolysis, stored and used in hydrogen powered turbine.	• Cryogenic storage allows hydrogen to be stored at ambient pressure • Potential for seasonal storage • High efficiency of electrolysis process	• Renewable energy required for hydrogen production • Low efficiency in production • Electrolysers require cooling • Brine production • High operational requirements to operate chemical plant	515-1,300	Costs are decreasing as system efficiency increases and technologies become more mature
Hydrogen fuel cells - Hydrogen fuel cells convert the chemical energy of a fuel into electricity. They can be used to provide backup power when renewable energy supply is interrupted or not large enough to match demand.	• Clean, zero carbon emissions with hydrogen fuel	• Requires hydrogen as a fuel source. If produced from methane reforming, CCS needed to be a low-carbon option. • High Capex	3,000	Increasingly mature but not for grid storage. Currently being developed in the Orkeny Islands to run ferries and widely used in buses.

Liquid air energy storage (LAES) - Uses excess electricity to cool air until it liquefies, this can then be stored in a tank. When the stored energy needs to be utilised it is brought back to its gaseous form and used to drive a turbine.	• High power capacity solution. • Long lifetime relative to batteries. • Not as geographical constrained as pumped hydro.	• Not mature • Lower energy density than Li-ion • Relatively round-trip efficiency	Developing technology	Developing technology
Pumped heat electricity storage - Electricity is used to drive a heat pump which charges a hot and a cold thermal store. To recover electricity the heat pump is reversed to become a heat engine.	• High power capacity solution. High power capacity solution. • Likely to have a long lifetime relative to batteries. • Not as geographical constrained as pumped hydro.	• Not mature • Lower energy density than Li-ion • Relatively high round trip efficiency, but likely to be higher than liquefied air energy storage. • Progress has slowed suggesting technological or cost barriers need to be overcome.	Developing technology	Developing technology

6.2.1 Lithium ion

Lithium-ion technologies dominate the energy storage market across applications in the near term, particular in geographies and situations analogous to Greater Brighton. According to a recent energy storage technology report by the US DOE, they offer the "best option in terms of cost, performance, calendar and cycle life, and technological maturity" for a battery system.

6.2.1.1 Costs

The majority of the battery system costs are due to the manufacturing of the energy storage unit, the battery pack itself. The volume weighted average lithium-ion pack price was of £135 per kWh throughout 2018. This already competitive price is expected to fall further as a result of improved energy density at the cathode material, cell and pack level. In 2025, it is expected to be at £69 per kWh and in 2030 as low as £49 per kWh. This trend has been driving down the cost of the entire system, which apart from pack itself also comprises the power conversion unit, the balance of plant and construction and commissioning charges. Current capital cost ranges for whole systems are presented in Figure 6—2, classified per project type.

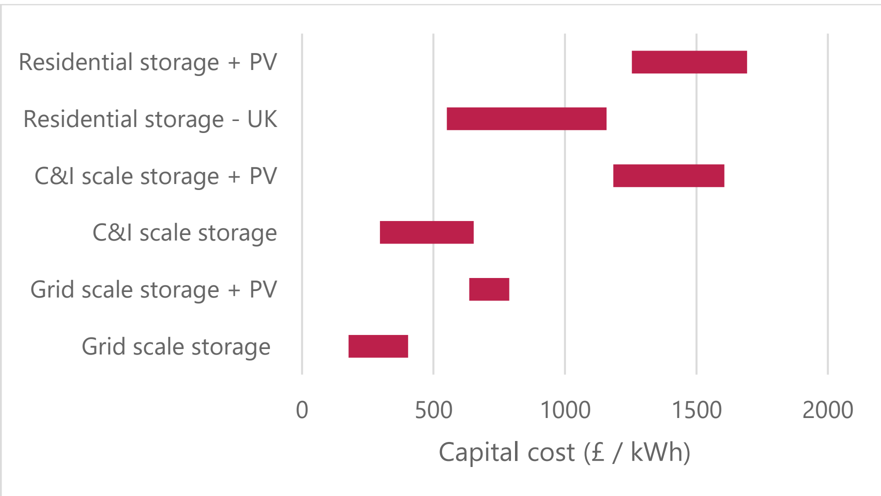

Figure 6—2 Lithium-ion battery cost analysis.

Economies of scale are clearly a factor in reducing the capital costs of grid scale installations of the order of more than 10 MWs. Commercial and industrial storage facilities up to 2 MWh and residential storage between 5 - 14 kWh suffer from much higher unit costs, particularly the latter. Several companies (e.g. Tesla, Sonnen and Powervault) are now trying to enter the residential market by betting on its time-shifting potential to increase self-consumption of domestic rooftop PV installations, but upfront costs are still quite significant, especially when taking into account the PV investment. Per kWh costs are again more reduced for a grid scale generation and storage plant.

6.2.1.2 UK position

The bulk of the manufacturing capacity of Li-ion batteries is currently in China and is projected to remain there with future EV uptake trends. Europe forms the second largest manufacturing region, with the UK playing a pivotal role as it hosts the continent's largest automotive Li-ion battery electrolyte plant and main producer of BEVs with an annual capacity of up to 30,000 single battery packs. The UK has a very strong network of chemicals companies capable of supplying the basic building blocks of Li-ion batteries, namely cathodes, anodes and electrolytes. Many directly supply the Asian battery market and often hold significant market shares. Since 3/5 of the value is in the chemicals and materials, there is a massive £4.8 bn year supply chain opportunity that can be built by 2030. The government has shown a degree of interest in developing this market through the Faraday Battery Challenge (FBC), Advanced Propulsion Centre (APC) and the UK Battery Industrialisation Centre (UKBIC).

6.2.2 Revenue streams for storage

Ancillary service products, demand response and demand charge mitigation represent the most attractive revenue streams available to storage projects in the UK. Batteries have the capacity to shift for a short or more or less extended period of time electrical energy and therefore address both electricity peak demand times and shortages of renewable energy supply. National Grid values these ancillary services in a UK market that requires an increasing amount of demand-side flexibility with greater penetration of intermittent renewables. Niche market segments have developed as a result; they are discussed below, along with other primary time-shift and demand response services that batteries have to offer:

- **Wholesale energy arbitrage** – it involves storage of relatively cheap electricity (either produced from renewable energy sources or purchased during low demand periods) to sell at higher prices in the wholesale market.
- **National Grid's Balancing Services** – when the wholesale market closes an hour prior to the half-hour period and the contracted positions of all parties are available, the TSO requires these types of services in order to balance the system and manage real-time electricity supply and demand. The National Grid contracts these assets ahead of time through tender processes and remunerates them through availability payments (£ per hr) for pre-agreed availability windows and energy response payments (£ per MWh) when the assets are requested to come online. The services differentiate themselves in terms of the technical and contractual requirements, to attract different types of demand response technologies. Those that are accessible to batteries are described next. Their technical characteristics and market size are summarised in Table 6—2.

- **Frequency regulation** - this is the fastest response time of the Balancing Services products and is used to maintain the system frequency stable at 50 Hz. There are two types of frequency response market segments accessible: **Firm Frequency Response (FFR)**, which in turn is subdivided into primary, secondary and high response, and **Enhanced Frequency Response (EFR)**. They differ in the required timeframe in which they are expected to operate, as detailed in Table 6—2. While other types of technologies participate in FFR (pumped storage hydro, spinning thermals, interconnectors, etc.), the EFR market is almost exclusively aimed at Li-ion batteries given the extremely response time required and was borne out of the need to mitigate increases in the rate of change of frequency derived from recent renewables generation integration to the system. The first tender rounds were held by National Grid in July 2016 for 4-year long contracts, mainly for 24/7 provision. Contracts cleared at a lower cost (between £7 and £11.97 per MW per EFR hr) than some FFR contracts at the time despite the higher value of the service provided and around 1.2 GW of capacity had unsuccessful bids. This attests to the increased competitiveness of the Li-ion technology in the context of the UK electricity market and the significant market's appetite.
- **Fast Response (FR)** - this is the second fastest Balancing Services product and is better suited to larger assets, such as pumped storage units and fast start gas reciprocating engines, given the higher power provision requirements and slower response time required.
- **Short-Term Operating Reserve (STOR)** and **Demand Turn Up (DTU)** – these are the lowest response time and subsequently lowest value reserve products, suited for low running cost flexible large-scale plants. Their technical characteristics are detailed in Table 6—2.

Table 6—2 Response times for different storage services for the National Grid.

Balancing Service	Response time and duration	Minimum power provision	Market Size	Total remuneration (£ per year)
Enhanced Frequency Response (EFR)	Under 0.5 s for at least 15 mins	N/A	201 MW	16.5 million
Firm Frequency Response (FFR)	Under 30 s for at least 30 mins	1 MW	Approximately 2 GW	65.95 million
Fast Reserve (FR)	Under 2 mins for at least 15 mins	25 MW	Up to 400 MW	10 – 15 million
Short-Term Operating Reserve (STOR)	Within 4 hours, but within 20 minutes is preferable for at least 2 hours	3 MW	Up to 3 GW	50 – 90 million
Demand Turn Up (DTU)	Within an average of 6 hours, for an average of 4.5 hours	1 MW	N/A	N/A

- **Pricing arbitrage in the imbalance market** – the Balancing Mechanism (BM) is another real-time tool used by National Grid to manage system imbalances. All large scale generators and storage are required to notify National Grid before market closure of a set of prices and available volumes that the TSO can use to increase their output (offers) or how much they are willing to pay to decrease their output (bids). Today, this imbalance market can also be entered more recently by small-scale storage assets, through a BEGA agreement for example. This type of market is currently characterised by greater merchant risk and less income certainty; however, cash-out reform is expected to allow imbalance prices to reach £6000 per MWh in times of system stress, rewarding significantly flexible capacity providers such as Li-ion batteries.

- **Capacity Market (CM)** – annual auctions are held by National Grid to award fixed-price, 15-year long contracts to remunerate plants for being available during periods of system stress. Contracted assets are obliged to deliver energy (minimum threshold is 2 MW) by a four hour ahead warning, otherwise they face penalties. However, participants providing Balancing Services products are exempt from penalties and can still receive availability payments from the CM mechanism. As of March 2018, around 0.9 GW of energy storage had been awarded CM contracts.
- **Embedded benefits** – these benefits are reaped by small-scale plants not connected to the transmission network but only directly to the distribution system, which then avoid the relative Transmission Network Use of System (TNUoS) charges. They are usually monetised through commercial negotiations between the embedded generator and its off-taker(s) and vary by location and voltage connection level. Additional avoided costs can be monetised through a private wire or behind-the-meter connection. However, after an official review by Ofgem over the 2016-2017 timeframe, the TNUoS avoidance benefits have been reduced by as much as 95%, with additional avoided costs still under review. Clearly, this revenue stream is now governed by a relatively high level of policy risk and long term price risk.
- **Bill management –** this case use is more relevant to commercial and residential battery owners as it achieves reduction of demand charge using battery discharge and the daily storage of electricity for use when time of use (TOU) rates are highest.
- **Transmission & distribution referral** – batteries can provide the extra capacity that will be required as heat and mobility are increasingly electrified, thus delaying, reducing or avoiding transmission and distribution system investment. This service is not a developed value stream in the UK yet, but there are increasing discussions on calling on assets to provide this through the creation of Constrained Managed Zones.
- **Backup power -** Provides backup power for use by Residential and Commercial customers during grid outage. If storage systems will be used during outages they need to be able to be isolated from the grid for health and safety purposes.

These various options are given context in Table 6—3, which explores the different markets various revenue streams and storage applications can unlock.

Table 6—3 Markets for different storage revenue streams and customers.

	Wholesale markets	**Single buyer markets**	**Network cost savings**
Margin (£ per kW per annum)	Up to £30	Up to £55	Up to £25
Revenue streams / demand charge reduction strategies			
Wholesale energy arbitrage	X		
Balancing Mechanism (BM)	X		
Frequency Response		X	
Fast Reserve (FR)		X	
Short Term Operating Reserve (STOR)		X	
Demand Turn Up (DTU)		X	
Capacity Market (CM)		X	
Bill management			X
Embedded benefits			X
Customer segment			
Grid-scale (above 10 MW)	X	X	
C&I-scale (below 10 MW)		X	X
Residential (2 - 5 kW)			X

As described for the Balancing Services products, the fastest the response required by the service, then the higher its value is and consequently the higher the competition for the tenders made available by the National Grid. This is reflected in Figure 6—3, with the frequency response services being the most valued. EFR would be more valued than FFR, but this differentiation is not made in the graphics.

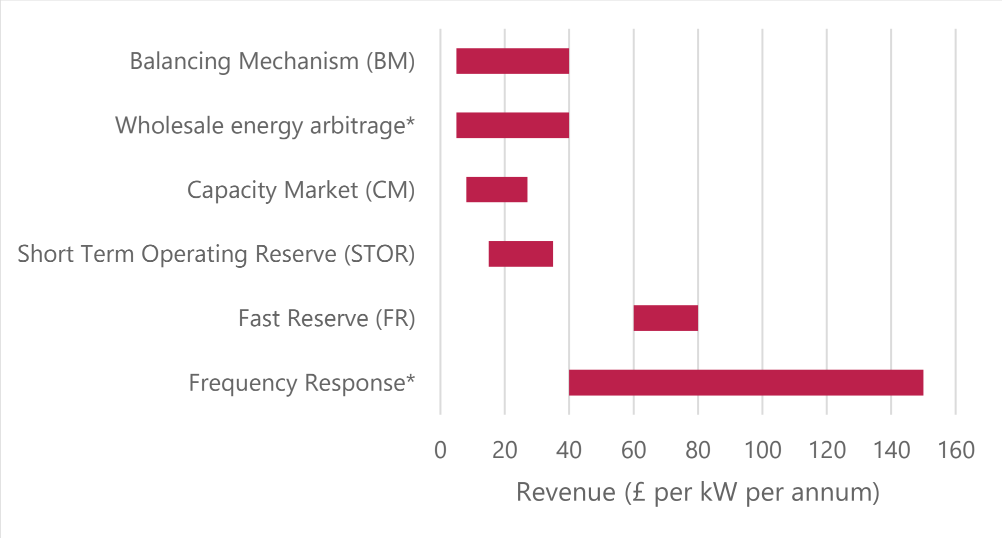

Figure 6—3 Economic value offered by different storage services. (* indicates that the corresponding services can bring about additional revenues per kW of capacity than the one illustrated by the bar).

The value in the Capacity Mechanism is relatively low, but it can be aggregated along with other balancing services; in addition, a direct advantage is that it is governed by much lower policy risks and long-term price risks, since availability payments are ensured for 15 years. Participation in the merchant power market (through energy arbitrage and the BM) brings about higher revenue risk but decreases significantly the policy uncertainty risk which characterises the National Grid's Balancing Services. Another important consideration is that high spreads are required to justify the battery degradation resulting from the constant cycling to charge and discharge the battery daily.

6.3 Transport

As described in section 4.3 electric and hydrogen vehicles are seen as being key for transport decarbonisation in Greater Brighton. Biofuels were included as part of the Tri-LEP strategy, however, they are not seen to be of much significance for a Greater Brighton Energy strategy - with hydrogen and electric vehicles being the focus for transport decarbonisation.

6.4 Heat

This section focuses on heat pumps, as the scale of roll-out required is perhaps the most challenging element of the heat strategy. Energy efficiency is also discussed and whilst this is challenging it presents a non-controversial aspect of the heat strategy for stakeholders. Mention is also made of heat networks, although these are considered mostly in the project opportunities Section 6.6.

6.4.1 Heat pumps

Heat pumps are currently the most viable technology to pursue the electrification of heat, particularly in the domestic sector, and can be smoothly integrated with traditional gas boilers; they are also becoming increasingly integrated into heat network designs to low the carbon footprint of schemes. Through an input of electricity, they are able to extract ambient heat from the outside, usually cold environment and upgrade sufficiently its temperature for space and water heating. An evaporator outside collects the heat and transfers it to a refrigerant fluid, which passes through a compressor to reach a higher temperature suitable for the heating needs of the property serviced and is finally contacted through a condenser with the heating or hot water distribution circuits.

The performance of a heat pump is dependent on the ratio of the heat output over its electrical input, commonly known as coefficient of performance (COP). This efficiency measure determines the carbon and energy savings achieved and is highly dependent on the temperature difference between the external heat collector and the output to the property. The choice of the heat source significantly affects the heat pump performance; two main types exist depending on this configuration, either ground source heat pumps (GSHP) or air source heat pumps (ASHP). Another heat pump with more niche applications, due to specific geographies is water source/marine source heat pumps – in Greater Brighton the application of the later is being explored at Shoreham Port and Brighton Marina (although this is not as developed as the Shoreham study).

GSHPs rely on underground loop installations to extract heat from the ground. This represents a stable source of heat particularly during winter and therefore GSHP are characterised by relatively high COPs, at a much greater capital cost however. As a result of space and cost constraints, they are not usually considered for single properties but rather for district heating schemes. ASHPs rely on a small external ground or wall-mounted unit to extract heat from the air, which however is characterised by much greater temperature drops during winter, affecting COP performances. Generally, a COP of 2.5 is assumed for ASHP and 3.5 for GSHP. As the technology matures and efficiencies increase in the UK, combined average COP values for space and hot water heating of ASHPs are estimated to achieve values as high as 2.9 to 3.5 and 3.9 to 4.8 for GSHPs (DOI: 10.1039/c2ee22653g). Lower spatial footprints and upfront capital costs combined with ease of integration into existing heating systems make ASHPs more compatible than GSHPs for retrofits of housing stocks. This hybrid configuration between an ASHP and a traditional boiler heating system can be referred to as a hybrid heat pump system, which also includes a dedicated controller for optimising the operation of the two. The heat pump would be expected to meet the majority of the space heating requirements of the property (usually between 70% and 85%) with the original heating producing equipment acting as back-up option, particularly during peak demand days. There are a few technical characteristics of the heat distribution systems of these building types that make the simultaneous operation of the two technologies worthwhile:

- Heat pumps are usually undersized relative to the peak demand of the property in order to reduce the capital cost incurred and increase their utilisation. A common business case is based on designing ASHPs to meet the entire space heating demand of the property on an average winter day, assuming a continuous heating schedule. The additional heat demand load required during peak days would then be satisfied by the original heating system (including electric resistance heaters).

- Heating systems are usually activated in a twice day mode (e.g. 4 hours in the morning and 4-10 hours in the evening), requiring significant heat production during the peak hours to raise the temperature of a property that has cooled for several hours to acceptable levels. This operation mode is not compatible with a standalone heat pump system because higher flow temperatures might be required, prompting the ASHP to operate at lower COP values and sometimes even triggering the activation of a complementary resistive heater. This situation is exacerbated in old housing stocks, where high temperature emitters require flow temperatures of up to 80℃ while maximum output temperatures of heat pumps only reach 55℃. Back-up boilers are then a necessity to reach such high flow temperatures and can also help smooth out the ASHP operating profile, maximising emission reductions. The second benefit is also valid in the case of a continuous heating schedule during peak days, as mentioned in the previous point.
- ASHP operation in a twice day mode and also in a continuous mode during particularly cold spells can ultimately lead to a significant increase in grid demand during peak hours, exacerbating congestion of the distribution network infrastructure. In the absence of thermal storage flexibility, back-up boilers can help avoid this without causing a loss in comfort, effectively providing a peak-shaving service.

Table 6—4 illustrates that hybrid heat pump systems can bring about similar emission savings compared to standalone ASHPs at more reduced upfront capital investments for a typical semi-detached house.

Table 6—4 Annual emissions reductions relative to a gas boiler (90% efficient) and range of upfront costs of HHP and standalone ASHP retrofits for a typical semi-detached house (continuous heating schedule assumed) in 2017 & 2030. Using data from element energy Hybrid Heat Pump report.

Heating system retrofit	Emissions reductions relative to gas boiler		Upfront cost	
	2017	2030	2017	2030
HHP	51-41%	80-59%	6,088-7,713	4,502-7,413
Standalone ASHP	54-52%	85-77%	8,216-10,397	5,751-10,097

This is a result mainly of the peak time operation scenario; standalone ASHPs would operate at significantly lower efficiencies as described earlier on a relatively carbon intensive UK grid generation mix compared to a smoother, more efficient HP profile of the HHP system favoured by the back-up gas boiler compensation. In 2030, this potential gap widens as it is assumed the UK electricity grid is decarbonised to a greater extent, but HHP systems would still be able to achieve significant environmental benefits when operated correctly. Both 2017 and 2030 analysis assume the operation of both systems is in a continuous mode, as a twice a day operation mode would reduce the annual emission saving potential of a HHP system below 20%, and to a lesser extent that of a standalone system.

The substantially lower costs required for the HHP system both in present and future scenarios compared to the standalone ASHP system makes such retrofit particularly attractive. This is mainly due to the lower cost of the undersized HP component, the fact that a hot water storage tank is not required as a result of the presence of the boiler and above all that the replacement of high temperature emitters of a typical semi-detached house with low temperature ones is optional, while it is required for a standalone HP system as it is not able to achieve flow temperatures above 55℃. These HPP cost savings are achieved even though the replacement cost or installation cost of a new boiler and a controller is factored in the analysis.

Hybrid heat pumps are seen as a vital bridging technology with low risk as they are compatible with a hydrogen future, if this technology penetrates the heat vector. However, they can also be deployed now allowing the peaking power and security of gas to be retained and limited additional stress being put on the electricity networks in gas connected areas. Developing hybrid heat pumps also stops inaction in trying to empower near-term large-scale heat decarbonisation which is a risk if hydrogen is relied upon (particularly given the nature of the Greater Brighton area gas networks – which are not a priority transition area). In summary gas still has very important role to play in heat but hybrid heat pumps appear a sensible step towards large reductions in carbon emissions in heat whilst maintaining the benefits of gas. It also means the gas network is maintained if there is a future transition to hydrogen.

6.4.2 Heat networks

Heat networks are a well-established low carbon solution for heat. Factors like diversity of multiple loads on a network, easier integration of low carbon technology (such as heat pumps), lower cost thermal storage, utilisation of waste heat and economies of scale can help make such schemes more economically viable than individual building solutions. In this energy plan there is a particular emphasis on the use of waste heat from large central emitters (such as water treatment plants, supermarkets and thermal plants). The close connection between the energy and water panels should be utilised due to a high resource potential. Engagement with Southern Water showed that at CHP sites substantial amounts of heat are dumped – which could be utilised. Additionally, a project with Southern Water just outside Greater Brighton (in Eastbourne) is looking to utilise waste heat from the sewage system. This should be closely followed, with the business setup in terms of owner and provider, potentially informing similar projects in Greater Brighton. The scheme should also be followed as it will inform the technical and economic viability of such projects for Greater Brighton.

Previously heat networks were confined to urban environments, to take advantage of high heat densities. However, as the technology matures, and we move towards 5th generation heat network design schemes in rural settings are currently becoming more viable, with two projects (one in Firle and one in Barcombe) being identified by stakeholders.

To assess the viability of heat networks individual studies need to be carried out at potential sites, thus it is not possible to provide an initial pipeline for projects. There are however multiple studies which can be integrated, identified in the GIS work and stakeholder engagement (such as the Shoreham Port marine heat pump based network and the potential waste heat sources of large emitters).

6.4.3 Energy efficiency

As discussed in previous sections for heat this combines heat pumps and building retrofit. Like the rest of the UK Greater Brighton has a very large share of property with an efficiency rating below C. Community energy groups (e.g. BHESCo and Warmer Sussex) are active in in this field, particularly in fuel poor areas. Brighton and Hove are also actively promoting higher guidelines than central government for energy efficiency.

The advantages of energy efficiency are well understood as is their payback. However, they require high initial capital – which can be a challenge as can certain building architypes. Establishing suitable strategies for building architypes across Greater Brighton can help grow a local strategy and supply chain. An Energy Investment Company could help implement measures, by providing loans for pay as you save schemes and the combined purchasing power of the Greater Brighton area could help keep CAPEX of projects low – due to economies of scale.

Whilst technologies are available and should be promoted to make new buildings highly efficient, retro-fit of current building stock is more significant for Greater Brighton to reach its carbon targets. It is suggested that rather than the government targets of at least a D EPC rating this should be increased to a C to make the scale of energy savings required to hit carbon targets.

6.5 Community energy

Community energy as a sector has grown considerably over the last few years stimulated by government feed in tariffs. The 2019 State of the Sector community energy report commissioned by Community Energy England identified that community energy organisations across England, Wales and Northern Ireland now own 168 MW in electrical generation capacity generating191.4 GWh (equivalent to the electricity demand of 64,000 UK homes), as well as 3.9 GWh of heat. Community energy generation reduced carbon emissions by 56,000 tCO2e through renewable electricity and by 711 tCO_2e through renewable heat generation in 2018.

The Greater Brighton region is already benefitting from the development of community energy approaches. Community energy groups in the Greater Brighton region making a significant contribution in driving forward the development of new approaches to incorporation of renewable generation, through community engagement and developing commercially viable delivery models.

Benefits of a community energy approach are numerous including the acceleration of uptake of energy efficiency measures and renewable generation through community engagement and community owned delivery vehicles. In addition, community engagement reduces barriers in the planning process and can directly address concerns around fuel poverty through an inclusive model. Revenues generated from energy sales and savings made because of reduced energy costs can be circulated directly back into the local economy to improve community facilities.

Traditionally focus has been on the installation of solar schemes stimulated by the subsidies however community groups are now broadening community models to also focus on other aspects including heat and transport decarbonisation. Other models also referred to in the report include the Riding Sunbeams approach of connecting renewables into the railway system; which can be replicated as a model for the provision of low carbon generation into major consumers in the region.

Of particular relevance when considering community models is the positive impact it can have in contributing to off gas grid communities of which there are a number in the region. Many households in these communities rely on oil and large portions of housing stock may not receive sufficient heat from heat pumps in cold winters due to limitations in the ability to undertake fabric retrofits or install larger wet heating systems. The inability to use hybrid systems means many households will rely on the electrification of heat, which will result in high electrical infrastructure reinforcement costs, which will be further compounded by the need to electrify transport. A community approach to integrating the local energy system and incorporating the latest developments in 5th generation heat networks, heat pumps and community mobility models could significantly accelerate the uptake of low carbon solutions in this area through reducing energy costs and the requirement to reinforce electrical infrastructure.

It should be noted that concerns have been raised by some groups following the recent removal of the FiTs scheme as to the commercial viability of community energy. One of the recommendations made in this report is to consider community energy as a critical part of the strategy in delivering low carbon solutions in the region and therefore to consider support mechanisms that will allow the sustainable growth of community energy schemes. This should be done in conjunction with alternative commercial models, which can include community bonds, PPAs and possibly in the future peer-to-peer energy models.

6.6 Project opportunities

Through the questionnaires, workshops, various meetings ~200 individual projects were identified, six of these are explored in greater detail in Section 8. Projects are split into 17 key areas, some of these already represent viable business opportunities. Others may not currently have a strong economic case, due to the prices of incumbent technology (e.g. natural gas), there are complexities with these as the extra costs may be passed on to consumers creating issues with fuel poverty. However, in order to get close to reaching carbon targets in the desired timescales actions need to be taken in these areas. A summary of the projects is provided in Table 6—5.

Within these key project examples hydrogen is focused upon as a transport fuel, as it is considered the most near-term opportunity (which does not require other dependencies). Brighton and Hove Council sustainability are developing a Low Carbon Hydrogen strategy for Sussex. This includes trials for hydrogen boilers but as with this report transport and production form electrolysis using offshore wind is a focus. This broader hydrogen strategy is in keeping with the aims of this energy plan and should be integrated into any wider strategy.

Table 6—5 Summary of key projects and areas identified for delivering low carbon solutions. The values presented here are indicative based on known projects and scaling factors based on the Tri-LEP work.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Renewable Generation - **Solar Schools**	Many of the community energy groups in the region are involved in is solar schools. In essence energy group installs panel on school roof and sells the electricity through a PPA at a lower tariff rate than available from the grid but a higher rate than selling directly to a grid. The difference helps to payback investors, the schools are provided with cheap low carbon energy and it helps engagement with low carbon generation.	Several hundred schools at ~50-300kW depending on size of school. Full rooftop analysis of all sites would be required for more detail but seen to be ~15-30MW. Projects could also be rolled out to other suitable One Public Estate Assets.	Yes – currently reliant on a PPA between developer and the school. Neighbouring West Sussex County Council have 80 schools with solar energy installed. Demonstrating the potential of a sustained programme.	Community energy groups (e.g., Community Energy South, Brighton Energy CO-OP, OVESCO), One Public Estate, UKPN, schools in question.	EIC/Abundance model would offer large scale investment pool – that can increase roll-out speed. LA and One Public estate strong leverage to encourage uptake in schools. Encourage schools to reach out rather than be approached.	One Public Estate to be involved to effectively promote rollout at scale. A summary business proposition. LA based outreach to head teachers and boards of governors.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Renewable Generation – **Landfill Solar**	GIS analysis was undertaken to analyse suitable landfill sites – flagging 20 locations. Of these UK central Government data showed two as tapping landfill gas (although this can miss smaller sites) – which are considered in the tri-LEP report to be the best locations due to existing electrical infrastructure. Lindsey landfill site is considered the most suitable of these (in Arun) and is near other large scale solar developments. The second site in Beddingham (Lewes) could potentially be challenging to develop – the location is visually prominent in the National Park.	20 potential sites identified which would be able to achieve on over 6MW of capacity. Not all these sites will be viable, with two sites generating electricity from landfill gas being the most investible opportunities following the tri-LEP study model and have land available for over 12MW on each site.	Site dependent – large scale solar has limited support and is thus challenging without a PPA. Sites already using landfill gas present the best opportunity.	Landfill site owners, UKPN	Many of the major landfill site owners will be the LA members of Greater Brighton, meaning they can actively promote utilisation. If suitable sites are identified investment would be well suited to an Abundance/energy investment company style model.	Prioritise the Beddingham and Lindsey sites, and consult owner/ operators and key area stakeholders (e.g. National Park Authority) LA to review landfill assets. Carry out desk based solar assessment for these. Determine grid capacity in the area of landfill sites from UKPN.
Renewable Generation – **Riding Sunbeams**	Community solar projects which feed directly into rail traction systems.	Multiple arrays, seen to be of the approximate scale 3MW-15MW (currently three projects totalling 18.4MW). Additional sites are limited on suitable Network Rail locations.	Underdevelopment – awaiting review of trial. Investment to come from communities and commuters.	Network Rail, Riding Sunbeams, Community Energy South, Repower Balcombe, HKD Energy, Brighton and Hove Energy Services Coop	Currently a community model with limited Greater Brighton input required. Abundance style bond could allow greater and more rapidly available capital. Combining publicly held land assets suitable for development, e.g. landfill sites, could hold opportunities.	The recent introduction of the trial site in Aldershot will be monitored and if successful rolled out across identified Riding Sunbeams sites. Riding Sunbeams is currently applying for RCEF funding, pooling multiple projects to achieve required investment levels.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Heat/Energy Efficiency/ Transport/ Renewable Generation/Smart systems – **Rural off gas grid communities**	Uses a full energy system decarbonisation of an off-gas grid settlement. Key to this is minimising reinforcement necessary for a transition to renewable heat. Barcombe is progressing with a full decarbonising, including a shift from oil to electric heat (i.e. heat pumps), heat networks, community owned renewable generation, energy efficiency, and low carbon transport. Community buy in terms of active engagement and financially through community bonds is key. UKPN would partner through the NIC framework to show how rural off gas grid communities can decarbonise with minimal grid reinforcement. Other projects, such as a heat network in Firle, would develop similar key elements but Barcombe is unusual for its whole system approach.	Multiple rural communities across Greater Brighton and the UK.	In development – utilising multiple funding sources including community bonds	UKPN, Barcombe Community Group, OVESCO, Community Energy South	Outreach in combination with community groups and UKPN to engage other applicable settlements. UKPN's buy-in to the Greater Brighton is a key asset for solving these complex infrastructure issues in the region. Promote the flagship Barcombe project – which is of national significance (applicable to ~1.5 million UK homes).	The Barcombe project is currently through the first stage of Network Innovation Competition funding and so will progress based on this.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Heat - **Urban heat networks**	Heat networks are dependent on-site specific assessment. Key projects flagged include: Shoreham Port (confirmed as having undertaken HNDU study) using a marine heat pump (which is perhaps the most developed), Brighton Marina (also using a marine heat pump) through to Kempton (unknown HNDU status), two heat networks in Crawley (either having pursued or pursuing HNDU), and one in Newhaven – utilising waste heat form the energy from waste plant (at second stage of HNDU funding). In Eastbourne a collaboration is being explored, with Southern Water providing waste heat from a sewer. If the model works it could be applied across many urban area in Greater Brighton. Community energy groups, like BHESCO and OVESCO, are experienced at bringing forwarded smaller scale heat network projects. It should be noted rural heat networks are also considered in this strategy but taken to fall within the combined approach to off gas grid areas.	Several large scale ~15GWh/yr heat networks are identified at varying degrees of readiness. As discusses in other areas utilising waste heat may be vital for unlocking economic projects.	The technology is generally mature with multiple business models proven, site dependent economics are a key element.	LA, waste heat owners (e.g. southern water), BEIS (the HNDU framework), local communities, large anchor load heat users	Members LAs are vital as a driving force for HNDU work. Benefits to be had from collective learning and LAs own/operate many of the large anchor load buildings. Ability to reach out and engage waste heat producers and potential users for the heat.	Suitable project should progress through the HNDU frame work (like Newhaven for example) which will determine viability. The Eastbourne sewerage heated network should be monitored, if successful rollout across Greater Brighton. Integrate heat network assessment into local development plans.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Transport - **Hydrogen for buses and HGVs using electrolysis**	Utilise electrolysis to generate hydrogen for use in public and freight transport. The Rampion wind farm feed to the National Grid at Bolney is seen as a key strategic site for this – with the opportunity to purchase low price and zero carbon electricity for use in the electrolysis process. Electrolysis is water intensive and so close alignment with a water strategy is needed. Two other hubs are proposed at the region's two major freight ports of Shoreham and Newhaven. At Newhaven in particular production of hydrogen could be a challenge due to grid constraint. In both instances local renewable generation could be fed into the electrolyser – reducing system cost.	Requires LA commitment for the public transport side. Central government will be far more key at determining the scale of hydrogen in other vehicles, such as HHGVs.	Commitment has been shown by Brighton and Hove Buses (who also operate in Crawley). The initial case study indicates that economically diesel is still the better option but that a hydrogen hub is not dissimilar in cost compared to diesel. Gatwick airport has installed a Shell hydrogen fuelling station using on site hydrogen production, demonstrating demand.	Rampion Wind Farm, National Grid, OLEV, UKPN, Public transport bodies, Southern Water, Shoreham Port, Newhaven Port.	LAs in Greater Brighton are key for determining their public transport strategy, which is seen as the first mover for hydrogen. Brighton and Hove buses are early movers with this technology. A region wide approach is suitable for transport, allowing for pooled charging infrastructure.	Discussion to be had with Southern Water on water strategy to support H2 hubs. Map mobility requirements and cross map utility areas. E.g. are existing fuelling station locations near to suitable power and water infrastructure. Open up discussions with Rampion about the potential to purchase cheap power at the Bolney site (cheap low carbon).

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Transport / Renewable generation – **Solar car parks**	Pease Pottage service station is flagged as one of the region's largest greenhouse gas emitters (although not for carbon) and should thus be a focus. Large super markets would also be suitable sites, train stations (see Haywards Heath case study), ports, and any large non-shaded car parks (with an initial focus on any LA owned assets). Brighton Energy Co-op are actively exploring the potential for solar car park development.	Multiple sites across the area. Size varies depending upon number of charging points and roof/canopy availability. But ~100kW is certainly reasonable for large car parks.	Developing – based on the tariff difference between selling to electricity vehicle users and the grid. A key assumption to keep schemes economic is that charging points will be built anyway.	Community energy groups (particularly Brighton Energy Co-op) are leading in this area, LAs, EV solutions providers (e.g. Electric Blue), car park owners.	Ownership and ability to engage with car park owners. Driver of EV infrastructure. Could accelerate uptake in the area due to revenue stream opportunities and need of use for consumers who do not have off street parking/charging. Ability for cross LA learning. Integration into a wider transport strategy for the region.	Establishing pilot projects within the region. Reliant on utilisation so roll out should be phased with EV uptake.
Transport – **Electric vehicle charging infrastructure**	UK policy dictates a transition to EVs which will require associated charging infrastructure. Some of this charging will be carried out at home, however, many properties do not have the required driveways. Consequently, on street charging will be needed in addition to car park infrastructure and rapid charge points strategically located (e.g. at petrol station sites).	Large scale, with ambitions for a low carbon transport a near full transition to EVs is seen for small vehicles.	Required by government but through working with DNOs, smart charging and advanced mobility models costs can be reduced rapidly. This can also maximise return rates for charging points.	OLEV, LAs, carpark owners, UKPN, members of the public (for buy-in), supply chain (creating a standardised region wide approach).	Brighton & Hove have a developed EV strategy (in the top 20% of LAs according to a recent government survey), with important lessons and supply chain elements that can be shared between LAs.	Create a Greater Brighton transport group to help form a coherent region wide approach. Establish a region wide mobility model to inform strategy.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
	A mobility model is key to defining locations of charge points, and required rates of charge. There is also a public information element behind this, with the manufacturer's promised charging rates generally being superfluous to consumer needs.				Opportunity to create a region wide approach, which will be more user friendly.	Adopt London strategy approach of encouraging private developments to include charging facilities including public hubs.
Heat / Energy efficiency - **Hybrid heat pumps**	Hybrid heat pumps allow retention of the benefits of the gas network for dealing with cold weather heating requirements and boosting whilst providing increased efficiencies and carbon savings from heat pumps They are seen as a transition technology with low risk. They are compatible with a hydrogen future and if a higher electrification of heat occurs they will have helped users gain familiarity with heat pumps, easing the transition to a higher penetration of the technology. It is considered a low risk solution as it does not matter if hydrogen is not adopted. Schemes can also be semi-decentralised, i.e. with energy centres providing heat through heat networks and utilising hybrid systems (the FREEDOM project has some excellent learning in this area). Therefore, heat networks may utilise this or individual households. Large scale heat decarbonisation is vital to achieve carbon targets and hybrid heat pumps are seen as a key enabler.	Should see wide scale rollout across the area - Particularly if concerns over heat system performance for certain building clusters (e.g. where deep retrofit would otherwise be needed). This can also provide a semi-centralised solution, offering a containerised heat network solution.	Relatively new technology but heat pumps (air source) in general have a payback rate of 11 years compared to gas in a domestic setting.	UKPN, SGN, Central Government, LAs, heat engineers (who will need to be reskilled), community energy groups.	Ability for largescale procurement. By Greater Brighton LA members utilising the technology in their own stock it will help build a supply chain and encourage reskilling. This is vital given the deployment scale required. Ability to set up trusted trader schemes and training programs for installers.	Trial scheme in LA owned housing stock. Partnering with SGN and UKPN. This is a major central government solution. It should be establish what level of support available would be available for a large scale trial. Assessment of building stock to effectively target for the technology.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Energy efficiency – **Retro-fits (building fabric)**	Much of the UK building stock is very poor in terms of energy efficiency. This needs to be improved across all sectors. The number of actors generally makes this harder in a domestic context (particularly private land lord) and retrofit costs can currently be prohibitive for certain demographics. Current policy is to raise all rented properties to a minimum of E (this would result in an improvement in 6% of households). However, 64% of households (149,000 out of 233,000 EPC certificates) have an energy efficiency of D or below and it is bringing this up to a C grade which is more representative of the scale of change required. Energy efficiency installations should be coupled with new thermostats to realise maximum benefits. The LOCASE scheme being offers support for energy efficiency for non-domestic applications and is seen as key for enabling smaller businesses to become more energy efficient.	Large scale across domestic and non-domestic sectors. Targeting ~6% of domestic stock initially but applicable to at least 64%.	Proven to be cost effective Savings are technology and application dependent. Grant Schemes are available including the LOCASE scheme (available across multiple applications). Bonds/crowd funding providing capital for pay as you save schemes have also shown success.	Community energy groups are active in this area, including BHESCO, OVESCO, Community Energy South, Warmer Sussex, University of Brighton.	Greater Brighton LAs have a large building stock which should be the initial focus. Lessons learnt can apply across the area. Build up best practice for different building typologies leading to a more efficient application of technology. Existing LOCASE scheme to learn from and build upon. Considerable community energy experience, with a focus on those most vulnerable.	Segmentation of consumer groups and property owners to optimise fabric retrofit. Deployment across public assets. Create local requirements for private land lords. Scale up community groups targeting of fuel poor areas. Utilise the LOCASE scheme to improve energy efficiency in businesses.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Heat - **Anaerobic digestion to create biogas**	Waste materials to be anaerobically digested, the biogas generated is generally utilised either onsite (normally using CHP technology), or fed into the gas grid (for which it requires substantial cleaning.) Southern Water are already utilising anaerobic digestion extensively onsite so this feed-stock is already accounted for. Another key feedstock is from agriculture, notably the dairy industry. However, this industry is generally in decline in Greater Brighton, raising concerns about economies of scale. Refuse could be used but only one site was identified in Greater Brighton, in Burgess Hill, and this is currently stalling. Similarly the tri-LEP report only identified one project by name which is currently not progressing. Consequently, it is difficult to assign large scale rollout across Greater Brighton. However, in the stakeholder engagement processes SGN flagged injection into the gas grid as a key consideration so it is included here.	Currently there seems to be limited opportunity for injection into the gas grid, however, a trial waste digestion site would provide important lessons.	The technology is proven and gas injection is currently taking place taking place in the UK. Consultation on previous projects with farmers showed the payback to be slow but viable. The greater interest in adoption being sustainability rather than economics. CHP and anaerobic digestion are coupled at many sites and established as financially viable.	SGN, waste companies, farmers, Southern Water	Operation of waste companies and multiple farm sites can help pool together suitable feedstocks. This opens up opportunities for farming cooperatives for pooling of feedstocks and equipment to increase financial viability. SGN are already engaged, who would be a key player.	The challenge is seen as identifying a practicable feedstock and suitable site. A trial project should be bought forward between a waste company (Local Authorities can provide leverage for this or direct ownership) and SGN. From this scale and suitability for wider rollout can be assessed.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Renewable generation / Heat - **Utilising the potential of large greenhouse gas emitters**	Large emitters either have high energy consumption and thus a good target for low carbon technology or they can be sources of waste heat. Included are thermal power plants which will have a high level of waste heat which could be utilised in heat networks. The EU project Life4HeatRecovery, examines the heat opportunities by these large producers in more detail. A summary of the 50 sites are identified is: 16 supermarkets, 9 building materials manufacture sites, 6 water and sewerage sites, 5 other commercial sites, 4 crematoria, 4 waste sites, and 4 other. All emissions are considered in this identification (not just carbon) to identify the largest potential sites (also users of grid electricity will not be fully capture in terms of carbon).	Site dependent, but for example a large supermarket can produce enough waste heat for the equivalent thermal load of several hundred houses (~300). It should be noted that the grade of heat is important – as waste heat from sources like supermarkets can be very low grade (and thus hard to harvest).	Examples are seen for waste heat, which could be drawn on. For generation, onsite utilisation is a well-developed model and although new solar car parks are seeing high levels of interest.	Business operators, community energy groups, Local Authorities (to convene development), users of the potential heat networks.	Ability to take relevant projects through the HNDU support schemes. Combined approach to build a local supply chain. Local authorities can access HNDU support to carry out detailed feasibility studies. This could follow on other LAs lead, such as Plymouth who are actively exploring 5G heat networks, geothermal coupled with building waste heat and St Helens which are focussing on EfW and factory waste heat sources.	Initial desktop assessment of loads around major emitters. Outreach to emitters if suitable loads identified for heat networks, to see if excess heat is available and whether they would be willing to enter an agreement. Engage to determine interest in developing renewable generation, either to provide for own usage or other applications (e.g. solar car parks).

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Renewable generation/storage - **Batteries and localised generation in grid constrained areas**	In grid constrained areas batteries could reduce stress on electrical infrastructure and also allow further integration of renewables. The potential of this needs to be assessed on an individual substation basis. Dialogue is continuing with UKPN to determine the potential for these battery services. Discussion with UKPN revealed that in Newhaven the use of multiple domestic battery packs removed the grid constraint from the area (this only required ~30 minutes of warning and ~30 minutes of storage). Storage systems also allow access to additional revenue streams such as the capacity and flexibility markets as well as potentially maximise revenues through PPA agreements.	Battery systems can vary from the large substation based options (~50MW) to a domestic level (~4kW). With the latter being pooled to offer considerable value	There is significant arbitrage potential for battery schemes in this context. The interest of Pivot Power installing ~50MW batteries at National Grid Substations demonstrates this. Newhaven also shows that in grid constrained areas domestic level storage can also be viable depending on tariffs offered. Community level schemes are now beginning to consider battery storage to improve the business case.	Businesses providing balancing services (e.g. Pivot Power), UKPN, home owners in constrained areas.	A strategic view across all of Greater Brighton would present larger saving potential on infrastructure investment than considering areas in isolation. Large consumers could benefit significantly from procuring energy through PPA from a combined renewable/storage system including local authority estate.	Establish scale and income streams batteries could provide at UKPN substations, this will impact hugely their economic viability. Engagement with the Piclo helps to identify priority sites for both centralised and decentralised solutions. Piclo is demand only – so connections also need to be considered through the heat map or discussion with UKPN.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Renewable generation - **Domestic solar PV**	Installation of PV panels on domestic roof tops is a well-established technology but is seeing stagnation due to the end of the FiT. Local initiatives like bulk purchase schemes are seen as key for addressing issues with economic viability. There should be an aim to couple with other low carbon solutions where possible, such as heat pumps and EV charging to improve the business case. Community based models may provide additional incentive. Resilience may also play a key part in the future if the local power infrastructure becomes less reliable leading to uptake in solar/battery schemes to provide backup power; noting however that configuring domestic electrics to support this is more complex than traditional arrangements and therefore more expensive.	Multiple cases of ~4kW, could foreseeably combine based on FiT data to an additional 2.5MW per annum.	Currently the lack of tariffs means the business case is poor. This could be improved by bulk purchasing schemes and new community/ aggregating models.	Householders, Local Authorities, installers	Potential for bulk purchase of equipment to reduce costs. Active community energy groups means the area is in an excellent position to offer advice to households.	Set up bulk purchase provider for PV, to allow domestic projects to benefit from lower equipment costs.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Renewable generation - **Non-domestic solar PV**	Some of the key opportunities for this, such as schools, have been explored elsewhere. However, there are still a considerable number of opportunities for non-domestic based PV. This would include rooftop applications in addition to large solar fields. In the case of the latter it is suggested to achieve maximum benefit it should be combined with providing heat and/or transport. This is the case in Barcombe where in a field next to a church, which relies heavily on electric heating. Community energy groups in the area have a strong history in this sector, with the Harvey's depot project being a flagship project for community energy. PV farms may also provide real benefit through sleeved PPAs to provide a source of low cost, low carbon energy to large users who cannot generate sufficient quantities locally.	Large companies, such as supermarkets, will generally have their own strategies in place and will have potential for several hundred kW schemes. SMEs could vary from tens of kW to a similar scale as seen in supermarkets. Based on FiT data up to 2MW a year is taken to be reasonable. Larger scale solar farms can still be viable through sleeved PPA agreements and revenue stacking.	Economies of scale means large scale non-domestic consumers can achieve relatively good payback rates (anecdotally 10 years can still be expected). Various PPA mechanisms have been shown as effective in the area by local community energy groups. Sleeved PPA allows the use of DNO networks to provide energy to other locations at competitive rates. Incorporating energy storage can further add value through access to revenue stacking.	Businesses, community energy groups, universities.	The universities of Sussex and Brighton have various research schemes empowering SMEs in particular to adopt low carbon energy. Strong history of engagement and success with community groups in Greater Brighton.	Create a forum for interested businesses to come forward rather than be approached, which tends to be the case currently. A portfolio of projects like this would suit an Abundance or Energy Investment Company proposition.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Heat - **Biomass**	Biomass if sustainably sourced can be a useful source of low carbon fuel in some communities, either for individual properties or through heat networks. Coppice approaches are considered best practice from a carbon perspective as it results in better managed woodland with a higher carbon sequestration rate. There are several local wood fuel suppliers with a focus on sustainability. Problems have arisen in some applications around variable feed stocks, which presents challenges for heat system functionality. Applications reported in the stakeholder engagement include a biomass boiler at Lewes Prison and a biomass boiler as part of a proposed hybrid heat network in Firle including heat pumps.	Considered to be small scale with some localised application. Small scale is seen as desirable to ensure sustainability and promote the local supply chain.	Biomass boilers have seen relatively wide deployment in the UK. However, there can be technical challenges due to variations in fuel.	Wood Heat Association, Forestry Commission, users of suitable scale (e.g. rural properties and small heat networks)	Embedded supply chain with good sustainability credentials. Off gas grid areas where biomass can provide an alternative fuel to oil. Projects which are already looking to integrate biomass	The Firle heat network project, if it goes ahead, presents an interesting application of a rural heat network using biomass and ground source heat pumps. Lessons from this would be valuable for similar communities across the UK. Promote preferred suppliers to maintain a strong and sustainable local supply chain.

Theme and project name	Description	Scale	Proven business model	Key stakeholders	Greater Brighton action/added value	Next step
Heat – **Solar thermal**	Solar thermal has lagged behind solar PV but is supported by the RHI and could have significant potential for properties where there is room for a large hot water tank. There is now technology that couples PV and thermal power which could be useful to optimise the use of roofspace. Analysis shows that decarbonisation of heat is of the greatest value and therefore solar thermal could provide more benefit than solar PV depending on the application. It should be noted of course that a PV system may still have high value in this regard when combined with a heat pump and/or EV charging and can also use a secondary coil for water heating in tank systems. Large solar thermal has been examined in the area for use on leisure centres, the large roof space and high heat demand seems to make solar thermal an ideal application There could be potential applications in district heat networks which BEIS are investigating as an area of interest across the UK.	Potential across Greater Brighton due to solar resource. Roof space allocation to optimise ration of PV and solar thermal needs to be considered. Duel technologies will help avoid this. An aggressive 10% equivalent to domestic heat demand (this would also be spread across non-domestic applications) is placed on solar thermal in the modelling.	Currently low deployment rates raises questions over the economic model for domestic properties but the RHI does provide substantial financial incentives in this area. Similar models for solar thermal as seen in PV, i.e. an HPA instead of a PPA, could be used to aid deployment.	LAs, community energy groups, central government, large heat users, home owners.	LA owned building stock can have panels installed, where appropriate. This could help to reinvigorate the supply chain. For large scale applications, like leisure centres, Abundance style investment or an EIC approach. Potential for bulk purchase to bring price down at a domestic level.	Investigate feasibility of solar thermal on leisure centres (focusing on LA assets initially). Drive to promote solar thermal in the area – bulk purchasing power as with PV would assist with this. Monitor opportunities for solar thermal heat networks coming from BEIS.

To give greater context to the projects described above provides an indication of the speed of deployment available for different project areas, their ease of deployment (taking into account technological readiness and financial viability) and their carbon impact. All projects identified have immediate actions which can be undertaken so this is more an indication of large-scale rollout rather than individual test sites or actions within a project area. For example, individual heat networks, such as Shoreham are quite far progressed, but large-scale rollout even if the decision to develop was made immediately it would be far slower to realise than deploying solar power on schools.

Table 8—1 Qualitative assessment of different project areas speed and ease of deployment and carbon impact.

Project area	Theme area	Speed of deployment	Ease of deployment	Impact (CO_2 savings)
Solar schools (and other One Public Assets)	Renewable generation	High	High	Medium
Landfill solar	Renewable generation	High	High	Medium
Riding Sunbeams	Renewable generation	High to Medium	High	Medium
Rural off gas grid communities	Heat/Energy efficiency/ Transport/ Renewable generation/ Smart systems	Medium	Medium	Medium to High
Urban heat networks	Heat	Medium	Medium to High	High
Hydrogen for buses and HGVs using electrolysis	Transport	Medium	Medium	High
Solar car parks	Transport / Renewable generation	High to Medium	High	Medium
Electric vehicle rollout	Transport / smart systems	Medium	Medium	Very high
Hybrid heat pumps	Heat / Energy efficiency	Low to Medium	Low (for domestic as opposed to semi-distributed, which would be similar to heat networks)	Very high
Retro-fits (building fabric)	Energy efficiency	Medium (highly varied)	Medium (highly varied)	Very high
Anaerobic digestion to create biogas	Heat	Medium	Medium to High	Medium to Low
Utilising the potential of large emitters	Renewable generation / Heat	Medium	Medium	Medium
Batteries and localised generation in grid constrained areas	Renewable generation / Storage	High	High	Low (primarily enabling and cost saving)
Domestic solar PV	Renewable generation	Medium (continuous deployment)	High	Medium
Non-domestic solar PV	Renewable generation	Medium (continuous deployment)	High	Medium
Biomass	Heat	High	High	Low
Solar thermal	Heat	Medium	High	Medium to High

Although most of the project opportunity areas detailed in Table 6—5 and Table 8—1 are single technologies there are opportunities to explore multi-vector projects, where different technologies may support each other. Examples, include solar car parks, rural off gas grid communities and combining renewable generation with batteries in grid constrained areas.

7 Delivery models

The successful delivery of local renewable energy projects requires tailored business tools and models. In order to best promote green energy production, the LA has at its disposal an extensive range of delivery models, involving engagement with private stakeholders if necessary. Possible approaches for the Greater Brighton region are suggested next, with a specific focus on solar energy projects.

7.1 Ownership models

There are a variety of different ownership models which can be taken forward for low carbon energy schemes, these are described below in Table 7—1 along with advantages and disadvantages of such schemes and an example application.

Table 7—1 Examination of different ownership models for low carbon energy schemes.

Delivery Model	Description	Advantages	Disadvantages	Example
Public Ownership	Public ownership involves public sector organisations leading the development of the project and taking the full financial risk. Elements of the construction and operation would be outsourced to the private sector through asset delivery contracts.	• Can bring about significant returns to be used for public / community purposes or reinvested in other renewable energy projects. • Easy integration into existing council structures, management routines and cross-sector networks. • Helps develop expertise in the field and elevate LA to energy leader status • Attracts private investment and engagement with other energy stakeholders.	• Exposure to a high degree of project risk in a field which might not be necessarily their expertise. • Requires organisational capacity and additional resources for the project management.	Solar on landfill sites – council owned, contaminated landfill sites with low productive value usually have a good grid connection and are therefore ideal for solar developments. This type of project is currently being developed by the Cambridgeshire County Council.

Private Ownership / In-House	A developer procures a long-term private sector partner to develop, own and operate a scheme on the developer site under a long-term concession. Ownership of the asset sits with the 3rd party organisation.	• Beneficial for highly technical or technology varied projects. • Externalises financial and operational risk and responsibility. • Addresses lack of willingness or capacity to increase council borrowing.	• The potential for lower returns of investment. • Reduced decision-making capacity. • Might be harder to retain economic and social benefits in the community.	Through the integration of three compatible technologies (solar PV, battery storage and electric vehicle charge-points), carparks can provide decentralised generation and facilitate the transition to e-mobility. These so-called solar carports can be deployed over several parking spaces in publicly and privately owned carparks through private companies that have developed this knowledge.
Community Ownership	The primary purpose of community ownership is to allow community members the opportunity to share the benefits of and invest in solar projects.	• Promotes inclusive growth, local engagement and community responsibility. • Already successfully implemented nationwide (168MW new installed capacity in 2017 equivalent to 71,000 tCO_2eq emission savings) • Can encourage further interventions across a wide geographical area.	• Can be very ambitious (maybe too much?) • Might require the setting up of an independent business structure. • Requires other stakeholders willing to buy the power produced. • Increased legal hurdles from stipulation of PPA.	Solar energy for Network rail - Small solar farms installed alongside Britain's DC electrified tracks can provide around one tenth of the trains' traction electricity demand each year. Over 50 technically viable sites have been identified, of which 7 are very promising as prospective community developers have been identified. Solar schools are another key example in Greater Brighton.
Spun-Out	This model entails the creation of an independent energy supply company out of the management structure of a parent company (which may well be a LA), usually to focus its resources and engage exclusively in the management of the renewable energy projects.	• More defined project delivery goals and resources utilisation of the new organisation. • Can dedicate more resources to the optimal management of the projects. • Gives more visibility to the renewable energy efforts of the stakeholder. • Freedom to develop in-house project management expertise.	• Additional time and sometimes financial requirement to set up spun-out company.	A common example is for a LA to create a municipal ESCO to develop and operate the energy systems of its residents.
Wholly-Owned	This similar to the spun-out model but is wholly owned by the parent company.	• Popular with LAs: • Governance constraints are less demanding allowing greater agility; • Allows control over providers; • Enables profits to be retained by the LA.	• Potential changes to public procurement rules • Potential conflict of interest with parent company	The 61MW(p), Wroughton Airfield Solar Park is one of the largest ground-mounted solar projects in the UK. It is a joint development between Public Power

			• Operational risk is concentrated one company (which is why LAs tend to use these vehicles in joint ventures).	Solutions which is a wholly-owned subsidiary of Swindon Borough Council, and the Science Museum Group (which owns the site).
Joint Ventures	This is an agreement that is entered for a number of commercial reasons including tax, funding or the location of the project. A common joint venture would be between a developer and a landowner with a site suitable for renewables such as wind or solar. By establishing a joint venture with the developer the income from the project in the hands of the landowner is treated as a trading income and qualifies for Business Property Relief (BPR).	• Resolves tax planning issues for the landowner of the location of the project. • Useful to clearly define contractual obligations, and degree of ownership of stakeholders. • Useful to combine complimentary expertise of different stakeholders • Opportunity to develop new resources, knowledge and capacities.	• Additional time and sometimes financial requirement to set up JV.	Lightsource BP, Europe's biggest solar energy developer, has formed a JV with Egyptian engineering group Hassam Allam Holding to develop, operate and fund utility scale solar projects in the country. Similarly, LAs can strike JVs to benefit from the technical expertise of certain engineering firms to develop solar projects in their area.
Special Purpose Vehicle	A Special Purpose Vehicle (SPV) is a separate legal entity created by a parent organisation (e.g. a LA). The SPV is the owner of all the rights, assets and liabilities of the concession. As the owner of the 'whole', will be the only entity who requests the resources to finance the project. Shares many characteristics with JVs/spun out companies/whole entities.	• Allows isolation of financial risk. • Potential for corporate and energy tax exemption. • Provides confidence for investors.	• Generally lower access to capital than the LA/founding organisation. • Regulatory requirements to consider	

7.2 Delivery models / power purchase agreements

As energy systems are changing and becoming less centralised, many are expressing a desire to have a stake in local, low carbon generation. A Power Purchase Agreement (PPA) is an agreement to buy power from an energy generator and in this case a renewable energy generator and can be a way of decarbonising electricity supplies (similar agreements can be put in place for heat, termed HPAs). In a PPA a contract is signed between the energy generator (seller) and the off-taker (buyer). PPAs offer a number of benefits that support the objectives of sustainability and finances in equal measures. A summary of different PPA strategies is provided in Table 7—2.

Table 7—2 Summary of different power purchase agreement options

Power Purchase Agreements (PPA) Type	Description
Behind the meter PPA	A behind the meter PPA is the most direct form of renewable consumption because the power is generated on-site, for example, ground or roof mounted solar PV or small-scale wind which can both be paired with storage. This can be financed at the business end where the user of the electricity finances the entire project with their own money and owns and operates the project. Or it can be financed by signing a PPA with a third-party investor who owns and operates the project and the business purchases all electricity generated by the facility.
Sleeving PPA	A sleeving arrangement, also known as third party netting, is a variant of a standard PPA between a licensed supplier and generator, it serves the purpose of linking the generation to the customer. This agreement allows the customer to purchase energy directly from the generating plant through a licensed supplier who manages the imbalance risk. A sleeving arrangement can allow a party to sell its own off-site renewable energy back to itself. The advantages of a sleeving agreement are that they are good for corporate responsibility purposes as they allow for organisations to link supply directly with renewable generation. Sleeving can also help financially if demand can be guaranteed and a long term PPA is negotiated. The disadvantages of sleeving are that this is not necessarily a cost advantage as the power is wheeled over the public network via a supplier which then incurs a cost. Without becoming a licensed supplier it is not thought to be possible to buy power directly from a generator and pay the necessary fixed costs to the network operators, a licensed supplier must facilitate the agreement. *Case Study: South West Water* South West Water has a sleeving arrangement with its electricity supplier, Total Gas and Power. This arrangement enables South West Water to buy back energy from its own renewable sites has been exported to the grid at market rate and therefore only pays delivery charges. The majority of the volume that moves through this arrangement surrounds South West Water’s two hydropower stations as well as a handful of other sites that export a small proportion of their generation to the grid.
Selectricity	Good Energy Group PLC currently offer a service called Selectricity which is a platform that matches demand and supply, it is open to business customers on the supply side and generators of all sizes. For example, a party that wants to support local energy generation can use that as a criteria. Good Energy Group PLC can then match the selected criteria and show a visualisation of the match on a half hourly basis, showing the percentage match of consumption and the number of miles from the specified location. Similar arrangements can be found with some other companies (e.g. Octopus Energy).
Self-Supply (Licensed Supplier)	There are options for self-supply which do not involve third party suppliers, however, in order to retain a licence, a number of industry codes and commitments must be followed. The advantages of self-supply include the full control over the purchasing and retail of electricity which is beneficial for larger generation projects (>100MW). The disadvantages of this method are the high costs involved in becoming an established supplier, as well as costs through the imbalance settlement and the high level of risk involved. *Case Study: Bristol Energy*

	Bristol Energy was launched in 2016 and is among a new wave of municipal energy companies with a full supply licence. Bristol Energy is wholly owned by Bristol City Council but it operates as a separate subsidiary. The objective of Bristol Energy is to deliver sustainable economic prosperity, reduction in social inequality and improved environmental performance. The company aim to achieve this by focusing on locally generated low carbon energy, supporting community investment in renewable low carbon projects and protecting the city's critical infrastructure which improves resilience. Bristol Energy can therefore support local businesses and generate a new revenue streams to be reinvested into the city.
License Lite	In 2009 the government introduced a licencing option called 'License Lite' which allowed generators to become licenced suppliers without becoming direct participants to industry codes. It was recognised that the costs of code compliance was disproportionate for smaller generators and was acting as a barrier to new, smaller generators and was acting as a barrier to new smaller suppliers. The Licence Lite supplier has to partner with an existing supplier (senior supplier) which complies with industry codes on their behalf. The advantages of this are there can be direct supply of generation to local customers and not through a third party. Regulatory costs that require compliance with industry codes are covered by the 'senior supplier'. It is also quicker and cheaper than setting up as a fully licenced supplier and encourages community buy-in. The disadvantages of this are that it still comes with costs and must enter the national market which means there is no option to be a local supplier.

7.3 Funding

Having a centralised strategic investment vehicle will help realise pipeline energy projects. It is suggested that the case for funding could be put through the City Deal framework. The Borderlands area of Scotland and England has recently been successful in attaining funding for the first stage of a similar project, a large part of the funding ask being for investment capital. The aim is to then attract outside investment, in addition to reinvesting profits from projects. The scale of a centralised Energy Investment Company (EIC) becomes a more attractive offer to large scale investors. A dedicated strategic EIC would also have the advantage of accepting lower rates of return than would often be looked for by traditional investors and could explore blended finance solutions for the risk stages of project development. The EIC would have a centralised panel, including central and local government and DNOs, which would make investment decisions. For Greater Brighton, an EIC formed of the wider infrastructure panel will help formalise the knowledge sharing process.

An agreed delivery vehicle linked to the Energy Investment Company could be a good choice to deliver carbon reductions and infrastructure resilience across the Greater Brighton Economic Board (GBEB) area. This could link with wider regional partnerships including the LEP, County Councils, NHS and Universities. The benefits of the investment vehicle in terms of scalability and a mixed public and private approach, can be applied to delivery vehicles also. On a smaller less formal scale we are seeing the benefits of a joined up approach across Sussex in the Your Energy Sussex partnership that has brought together local authorities to deliver an energy tariff scheme and is currently exploring a solar bulk purchase scheme for private households. A more formal commitment from member authorities to this kind of joint working could well deliver significant progress to meeting the ambitions of GBEB.

The delivery vehicle would need to have freedoms to secure funding from a variety of sources and deliver projects that can be scaled from one partner to the whole GBEB area. The scope can be determined to meet the local ambition and restrictions of varied areas with different governance and decision making structures. For example, it could be focussed on renewable energy projects as stand-alone carbon saving, energy resilience and fuel poverty alleviation to a more ambitious and broader scope taking in the connectivity offered through smart cities approach (transport, digital etc.).

Another model empowering a more crowdfunding based approach that could end up functioning to an EIC is that of community or Greater Brighton bonds. Particular note is given to the Abundance Investment model, with projects that would be suitable investable opportunities being flagged in the energy plan report. Having a project portfolio, for which the energy plan provides an initial basis, acts to increase scale - generally improving the investment opportunity and decreasing risk.

Economies of scale can assist in other ways as well beyond funding. A key example being bulk purchasing of technologies resulting in substantial reductions in costs. This model is being through Solar Together and iChoose for schemes in London, Suffolk, Manchester and Norfolk; where householders and SMEs register their interest to have solar PV installed on their roofs. With the support of Local Authorities these schemes can be pooled allowing a lower technology purchasing price. This driving down of costs for PV can help to overcome the challenges created for the sector by the removal of the feed-in tariff. The EIC could be an excellent vehicle to facilitate the bulk purchasing scheme. Alternatively, to achieve faster implementation, the Solar Together/iChoosr system could be adopted in Greater Brighton.

This approach of combined purchasing power could be extended beyond solar from batteries to hybrid heat pumps. This would integrate well with another characteristic of the Solar Together scheme, which is in addition to purchasing the technology install is also provided. A centralised government associated body like an EIC with trusted installers would help to increase consumer confidence, and thus uptake. A centralised installer will also allow bundling of technologies such as PV to provide power to heat pumps and energy efficiency measure into one package and joint install, simplifying a low carbon transition for consumers.

8 Case studies

Six case studies are examined in this sector covering a variety of vectors, technologies and geographies. These case studies are all scalable across other locations in Greater Brighton and this is highlighted within each study.

8.1 Bolney low carbon transport hub

This case study provides a summary of a potential project based around the Bolney National Grid substation – using the area as a focus for low carbon transport in the area. The key points highlighted in the case study are:

- Pivot Power interested installing a battery to act as a hub for electric vehicles and to provide grid response services.
- A PPA with the Rampion wind farm which feeds into the grid at this location would greatly improve the financial viability of an electrolysis scheme for transport – however, the diesel counterfactual option still provides the lowest cost option.
- Hydrogen for transport should be partnership projects between the Water, Energy and Transport (if it is created) Greater Brighton infrastructure panels.

8.1.1 Introduction

The Rampion offshore wind farm feeds into the National Grid at the 400kV Bolney substation. To achieve this an adjacent substation was constructed to provide uplift from the 150kV the offshore wind is transmitted from Rampion. The location and local geography of the two substations is illustrated in Figure 8—1.

Figure 8—1 Bolney substation area.

The two substations are surrounded by agricultural land, meaning location of additional energy services in the area is technically achievable. This potential has been noticed and the site is an area of interest for Pivot Power; who develop large battery storage projects connected directly to the transmission system, providing the electricity capacity for large-scale electric vehicle charging infrastructure throughout the UK. Additionally, they also provide balancing services, being able to compete on the high value frequency response markets.

Although the project is very early stages the indication is it would be in the order of 50MW in scale, an indicative space take would be 4,500m^2 (based on a similar recent battery) for a battery of this size is provided in Figure 8—1. Based on the latest figures from Lazard's this would be ~£15 million installation. If the battery was to be operating on the frequency response market it could generate £2,000,000 – £7,500,000 per year (assuming 40-150 £/kW/annum).

In addition to the proposed battery scheme it is suggested the substation would make an excellent site as a hydrogen hub for the Greater Brighton area. This is due to its centralised location being within 20km of Crawley, Gatwick Airport, Brighton & Hove and Worthing; and within 40km of the whole region – apart from a small portion of Bognor Regis. Figure 8—2 provides an illustration of the wider context of Bolney, with a back ground dataset showing land use – to highlight the urban areas (shown in red) and key transport and commercial sites – as these represent the focal areas for vehicle decarbonisation.

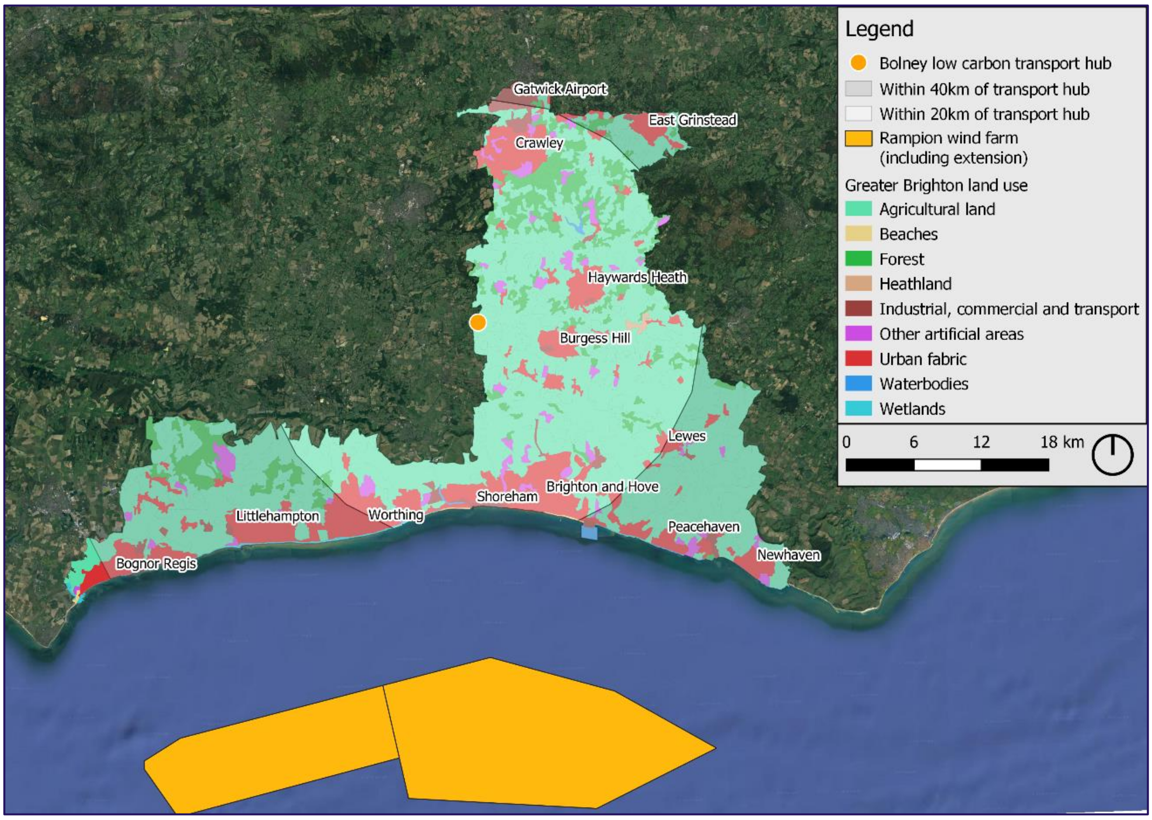

Figure 8—2 Bolney in the context of Greater Brighton. The EU Corine dataset is the source for the land cover information.

A hydrogen hub would create a strong case, beyond electricity grid decarbonisation, for expansion of the Rampion wind farm – as it would be directly contributing to decarbonisation of the transport sector.

8.1.2 Project description

This section outlines the key considerations for a hydrogen hub at the substation location. The initial outline focuses on buses but it would also be possible to build a hub for HGVs. Assumptions are based on a variety of source and scale and are a meant to be indicative, a full feasibility study would be required to fully assess the scheme's viability.

Table 8—1 Key considerations for electrolysis. Information is based on the 2018 Committee on Climate Change (CCC) – Hydrogen in a low carbon economy report; Department for Transport Annual bus statistics: England 2016/2017; International Renewable Energy Agency 2018 Hydrogen from Renewable Power report; and Hydrogen Europe: Hydrogen Buses.

Consideration	Assumption
Water usage	0.5 litres of potable water per kWh of hydrogen produced.
Potential hydrogen usage	26,500 miles per bus per annum, 8kg of hydrogen (266.64kWh) per 62.1 miles, for an indicative fleet of 200 buses this would equate to nearly 57 GWh of hydrogen a year.
Efficiency	67% (could rise to 82%)
Cost (capital)	300 £/kw
Cost (production)	The main production cost for hydrogen is the input electricity (~80%), the CCC put a cost on production at 90£/MWh however the price achieved at the latest CfD auction for offshore wind is 40£/MWh compared to the 72£/MWh which is inferred by the CCC. Thus if offshore wind were used for the hydrogen production through a direct contract with the wind farm the cost would be closer to 62£/MWh. Assumed water cost of 1.3 £/m^3.
Non fuel OPEX	2% of CAPEX
Operational strategy	Hydrogen production from electrolysis should prioritise use of renewable electricity, thus it should not be running at 100% of nameplate capacity – as an initial assumption it is taken that the electrolysis plant will operate at 40% of name plate capacity to account for this. Having spare capacity in this way also give the flexibility to ramp up production if demand requires.
System sizing	Based on an assumption of 57GWh of hydrogen a year and an electrolysis unit working at 40% of nameplate capacity this equates to a 24.2MW/16.2MW electrolysis unit (16.2MW hydrogen production with 24.2 MW electrical consumption). This would require 28.4 million litres of potable water and 85GWh of electricity. It is assumed the system will include storage for 1 day (which would be 1871 kg of hydrogen), which is taken to cost, along with fuelling infrastructure of £11million.
Counterfactual	It is assumed the counter factual will be a 9 mpg diesel at £1.37 litre. Investigation is also undertaken to find the price point diesel would need to be to represent a break-even system cost for hydrogen.
Vehicle cost	Cost such as vehicles are not included, due to required assumptions over replacement rates (200 new hydrogen buses would cost a further £44 million based on recently purchased hydrogen buses in Crawley), which would also be needed for the counterfactual case.

A simplified diagram of the low carbon transport hub, including the Pivot Power battery system is provided in Figure 8—3.

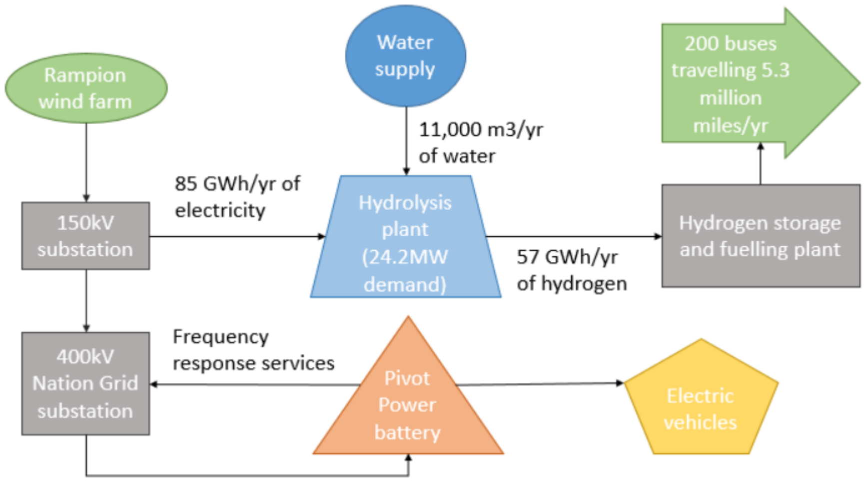

Figure 8—3 Simplified illustration of the Bolney low carbon transport hub.

8.1.3 Initial findings

Based on these assumptions the system would have an initial CAPEX of £7.2 million for the electrolysis unit and a further £11 million for storage and fuelling infrastructure, with running costs per annum of ~£15,000 for water, ~£3.4 million for electricity and ~£98,000 for non-fuel OPEX. If the project were to last 20 years, the total cost would be ~£88 million. It should be noted the pricings used are conservative and a lower levelised cost could be realised.

The counterfactual of diesel in that time would be a fuel cost of ~£73 million and to make the electrolysis system reach cost parity an average diesel cost over the assumed 20 year project period would be 1.66 £/l.

If a price is assigned to CO_2 emissions it can help recognise the additional benefit hydrogen brings. The CO_2 emissions from diesel are 2.62 kg/l, which over 20 years for the 200 bus fleet would represent 140 kt of CO_2. Currently the EU emissions trading scheme has a price of ~£22 per ton which equates to ~£3 million over the project lifetime. However, the EU ETS is increasing the carbon price to ~£50 by 2030 which would result in a CO_2 value for the project of £7 million.

This shows whilst the diesel counterfactual still represents the lower cost option, relatively few savings and adjustments from this initial outline need to be made to achieve cost parity. This is without taking into account other key factors like benefits to public health.

8.1.4 Delivery model

On the Tri-LEP matrix for project investment transport strategies of this type are considered suitable to be publically funded, private investment fund, or be backed by a finance institution. The application of this particular project for buses and the economics, which currently at best will reach parity with the counterfactual of diesel means it is not suited to private investors. A joint venture between local authorities in the area would be a suitable approach, spreading risk – which a Greater Brighton dedicated transport group would be very helpful in facilitating.

Partnership should also be sought with the Rampion wind farm. A guaranteed purchaser for electricity will be beneficial to the wind farm, particularly if the extension goes due the current low value achieved in the CfD auctions. Conversely a PPA in place with a large scale generator, which based on current data will be willing to sell far below the wholesale purchase price of grid electricity, improves the economics of the scheme. The flexibility of hydrogen electrolysis also insulates against variability in renewable generation – making it well suited to a PPA approach.

8.1.5 Scalability

The size of the hub could be expanded for more buses and to extend services to HGVs. Hydrogen is mainly seen for these applications rather than private vans and cars, where electric vehicles are considered the more viable model. Within Greater Brighton two further key sites for hydrogen have been identified, at the region's two major freight ports, of Newhaven and Shoreham. It is suggested onsite generation of hydrogen by electrolysis should be supported in these instances by co-located distributed renewable generation. Shoreham port are carrying out some initial analysis of hydrogen generation and a separate study of Newhaven identifies the potential for a large solar farm on an old landfill site, the output from which could be utilised for electrolysis.

Hydrogen produced by electrolysis is a water intensive industry. If a large scale hydrogen transition was to occur in the region Southern Water would have to be closely engaged, to ensure this low carbon solution does not exacerbate issues with water availability in Greater Brighton.

8.2 Newhaven – multi vector considerations

Newhaven presents many opportunities for multiple energy vectors, including heat networks and renewable generation. It is also in a grid constrained area which presents both some challenges and opportunities for low carbon energy projects.

8.2.1 Introduction

The town of Newhaven is one of the major ports in the Greater Brighton region, with cross channel freight and passenger ferries to Dieppe. The area has been made an enterprise zone to help drive business growth in the area. This business growth will bring with it increased electricity demand, which is a challenge as the area is already grid constrained. There are multiple opportunities and factors such as this in the area which would benefit from a combined approach to bring all these elements together so they can be managed in an effective smart system manner.

8.2.2 Project description

The Newhaven enterprise zone consists of eight sites spread across the town, these are displayed in Figure 8—4. Anecdotal evidence suggests uptake by businesses in some of these enterprise zone areas has been limited due to grid constraint on the UKPN distribution network, meaning there is not sufficient capacity to serve the increased demands. However, meetings with UKPN suggest immediate concerns over grid constraint have been overcome by pooling of domestic electricity storage. The storage contracts work on a basis of ~30 minutes warning and a storage run time of ~30 minutes; demonstrating relatively small levels of storage are required to alleviate current grid constraints (however, with a transition to electric heat and transport this is likely to change). It is likely some of the required flexibility was provided by generation within the area.

Newhaven also contains a major energy from waste plant, with an electrical generation capacity of 20MW. Currently waste heat from this site is not being utilised. This means there is a very large potential source of heat – which could be utilised for district heat networks; providing low carbon heat to both residential and enterprise zones without needing to cross the river Ouse which splits the town (see Figure 8—4).

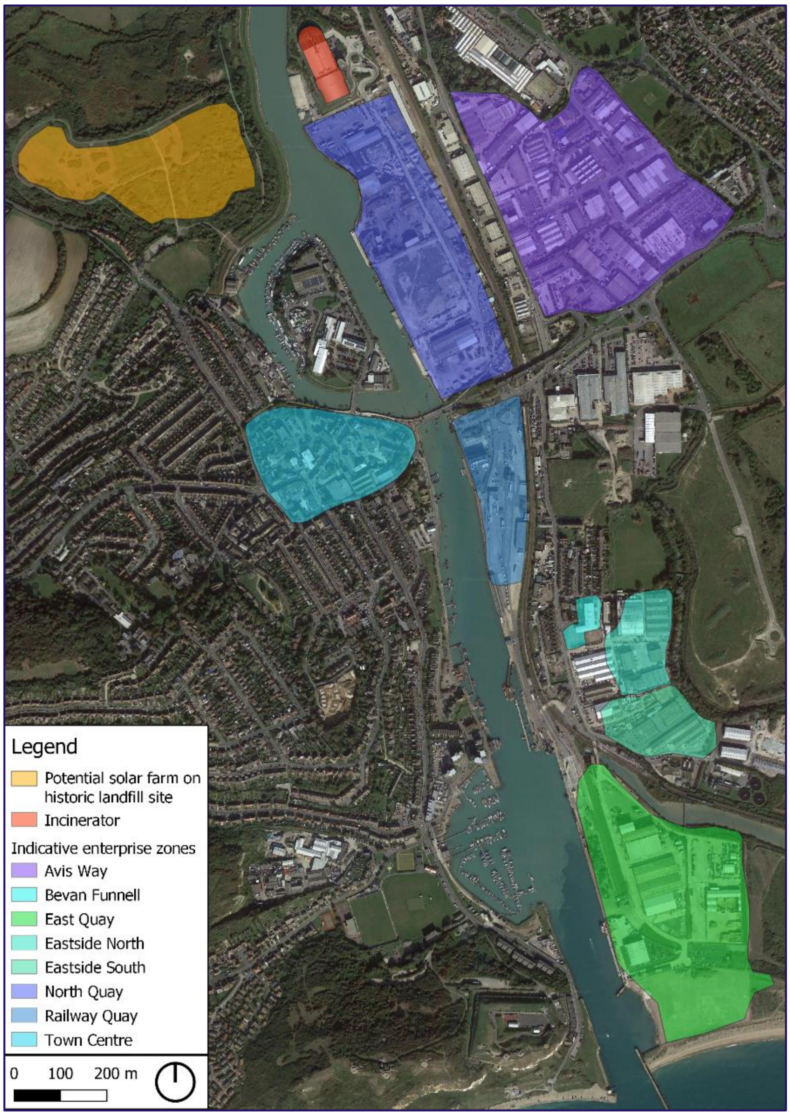

Figure 8—4 Newhaven area overview.

The town centre enterprise zone area, which lies on the western side of the town, represents one of the best areas for a heat network as it contains a swimming pool – which would make an excellent anchor load. To assess the viability of these heat network studies should be undertaken. Feedback from stakeholders indicates that this option is being explored through the HNDU support scheme.

Displayed in Figure 8—4 is a disused District Council owned landfill site, to the north on the town, which could be utilised for a ~20 acre solar farm of 7.9MW, generating ~9 GWh/yr. This ties in with the wider Tri-LEP strategy that identifies landfill sites as key for large scale solar, due to being contaminated (limiting what they can be used for), being low value land and being under Local Authority ownership – helping to streamline development. However, the grid constraint in the area could be a barrier to the project unless novel approaches are taken to integrate the power. If combined with batteries this solar farm could potentially reduce constraint at the primary substation level. Detailed discussion with key stakeholders, notably UKPN (the distribution network operator), would be required to assess the potential of this scheme.

The Enterprise zones have substantial solar on the roof tops. A detailed solar modelling exercise was carried out in GIS to examine this in more detail. It uses LIDAR data with a 1m x, y, z resolution - allowing building shadowing and roof angle and aspect to be assessed. As a result individual roof faces most suited to development are identified – an example is provided for the Avis Way site in Figure 8—5.

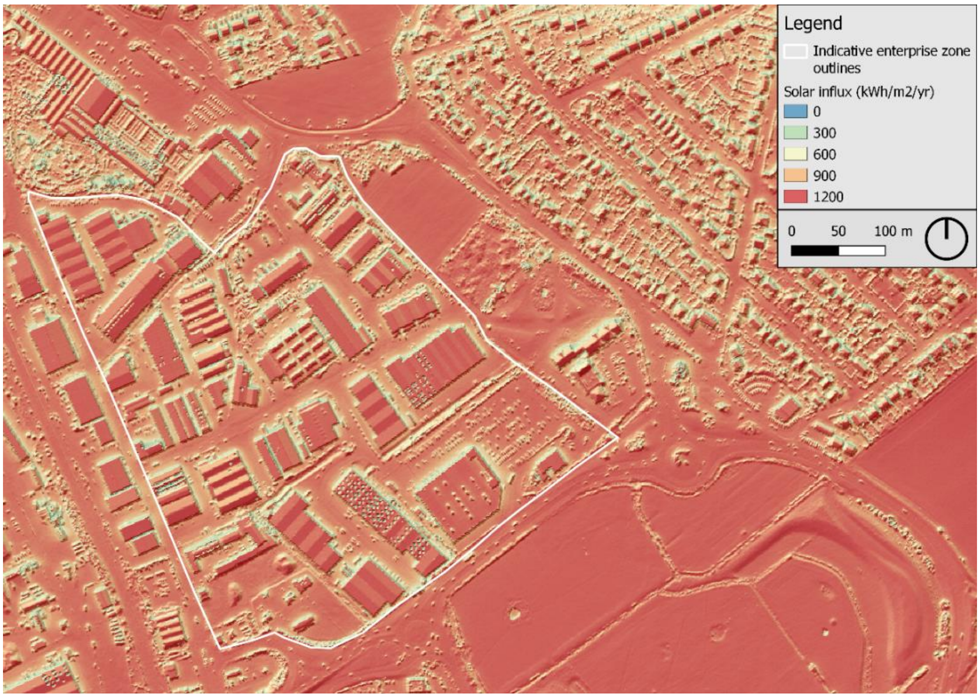

Figure 8—5 Detailed rooftop solar potential assessment at the Avis Way enterprise zone.

The final aspect of the strategy for the area is with the ferry port and associated HGVs it makes an excellent location for a hydrogen hub – similar to that described in the Bolney low carbon transport hub model. The solar farm on the disused landfill site could be a potential source of generation for an electrolysis plant. With the grid constraint in the area, unless reinforcement is developed anyway, an electrolysis plant would carry huge financial costs. This is because being an energy intensive process means upgrades to the network would be required if the plant was to be fed from the grid. Under the current distribution network operator model the cost of this upgrade would be met by this new consumer rather than spread – adding very high additional upfront costs to the scheme.

8.2.3 Delivery model/strategy

This project is multi-faceted, so different delivery models could be used in different aspects, however, the Enterprise Zone presents an excellent body to oversee a holistic cogent development strategy for the area – bringing benefits to both businesses and residents. Ideally this would include creation of a detailed energy master plan for the area, but for the specific areas the following breakdown is provided:

- **Heat networks** – a heat network feasibility study should be undertaken as this will help establish suitable clusters. This will alter which delivery model is most suitable depending on ownership. Discussions is currently being had with Veolia and HNDU supported assessments are being undertaken. Results of this feasibility assessment should inform the heat strategy.
- **Landfill solar** – If after more detailed assessment the site is shown to be financially viable it may be suitable for investment for a Greater Brighton energy investment company or similar vehicle. If a hydrogen electrolysis plant was set up it could supply electricity for this via a PPA or one operator could own both sites.
- **Rooftop solar** - Development models for rooftop solar could allow solar developers to lease roof space from building owners, pay the capital costs and sell the power via a PPA to the buildings. Alternatively, the building owner could have a self-owned model. The Newhaven Enterprise Zone could be an excellent facilitator for the project. It is suggested that solar panels for this development would be procured through a centralised purchasing scheme, to achieve the lowest equipment costs.

A next step would be to open dialog with the Newhaven Port Authority, there would be substantial opportunity for knowledge transfer with Shoreham Port – who currently have a more developed sustainability strategy. Veolia, Rampion and Southern Water (next to enterprise zone) located at the port, are all large-scale businesses who would be significant stakeholders in a project at Newhaven and should also be engaged.

8.2.4 Scalability

The port of Shoreham is further progressed with many of these options, including a heat network utilising a marine heat pump and consideration of a hydrogen fuelling site. Shoreham also already has wind turbines located on site and is wanting to expand their renewable generation potential, initial assessments indicates the resource would be suitable for a similar development in Newhaven. Shoreham forms part of the Worthing Digital Hub, which is a £32 million Innovate UK project with a private sector consortium - due to launch March 2020. This would integrate systems across a range of technologies - through exploring digital capabilities. Although it is smaller scale there could be similar potential for such a strategy in Newhaven; due, to the similar range of opportunities – being part of an enterprise zone is likely to help unlock these opportunities.

Whilst it is a very different port to Newhaven Brighton Marina could apply many similar options, including heat networks (stakeholder feedback identified this as an area of interest).

Beyond ports the potential of landfill sites and solar is recognised in the tri-LEP work as a key opportunity, which is scalable across the region. As part of this work an assessment of landfill sites suitable for solar has been carried out with about 20 being identified. Coupling these with electrolysis units and creating charging hubs for hydrogen fleets would aid a regional transition towards hydrogen for transport for HGVs and buses.

8.3 Barcombe zero carbon rural community

Barcombe is an off-gas grid community examining decarbonisation strategies, whilst this focuses on heat there also transport electricity elements. The latter being particularly important, to avoid expensive reinforcement with the electrification of heat.

8.3.1 Introduction

Barcombe is a rural off gas grid community with a heavy reliance on oil for heating. 25% of the homes are pre-1870 and the energy use per household is 175% above the national average. This is typical of many off-gas grid settlements, where older and less efficient building stock exacerbates the impact of higher carbon heating solutions. The community is pursuing a whole systems approach to decarbonising their lifestyle; examining heating, transport and power solutions. This is illustrated in Figure 8—6.

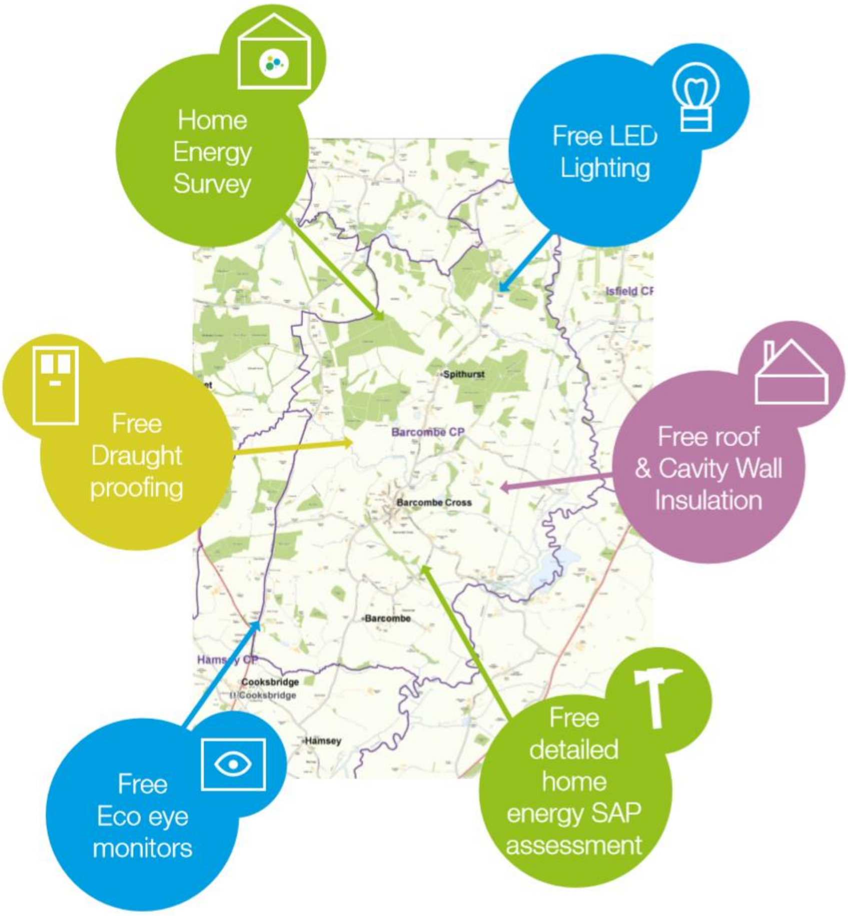

Figure 8—6 Barcombe project energy efficiency approach, from 2012 OVESCO assessment. The image is taken from OVESCO.

The suitability of an integrated transport, heat and power solution has already been undertaken for Barcombe by the OVESCO community energy group. Whilst the project examines all aspects of decarbonising the energy system in the community the focus is rightly on heat, given that this represent the largest challenge.

8.3.2 Project description

The scheme examines all aspects of decarbonising the Barcombe community:

- from retrofit solution for home energy efficiency and the local pub,
- to a broad spectrum of community owned renewable solutions (including wind, anaerobic digestion, solar, and micro hydro),
- low carbon heat through a local biomass supply chain, heat pumps and heat network solutions,
- transport and mobility solutions including a community electric bus and a cycling scheme.

Whilst these elements are all individually important for decarbonising the energy system it is Barcombe's approach to implementing these that make it such an innovative case study. Generally community energy schemes focus on incorporation of solar PV and rural heat pump installations are typically done on a customer by customer basis. However, Barcombe is looking to develop and explore new operating and commercial approaches in developing a community energy system. The heating infrastructure will be designed to make best use of local energy resource and reduce network reinforcement requirements. An example of this being a proposal to utilise land next to, and owned by, a local church for solar power. The heat demand for the church is very high, the aim being to power an electric based heating system with local PV; the location of the potential project and the solar resource is displayed in Figure 8—7. The resource at the site is good, with room for ~1.5MW of solar capacity, generating nearly 1800MWh/yr.

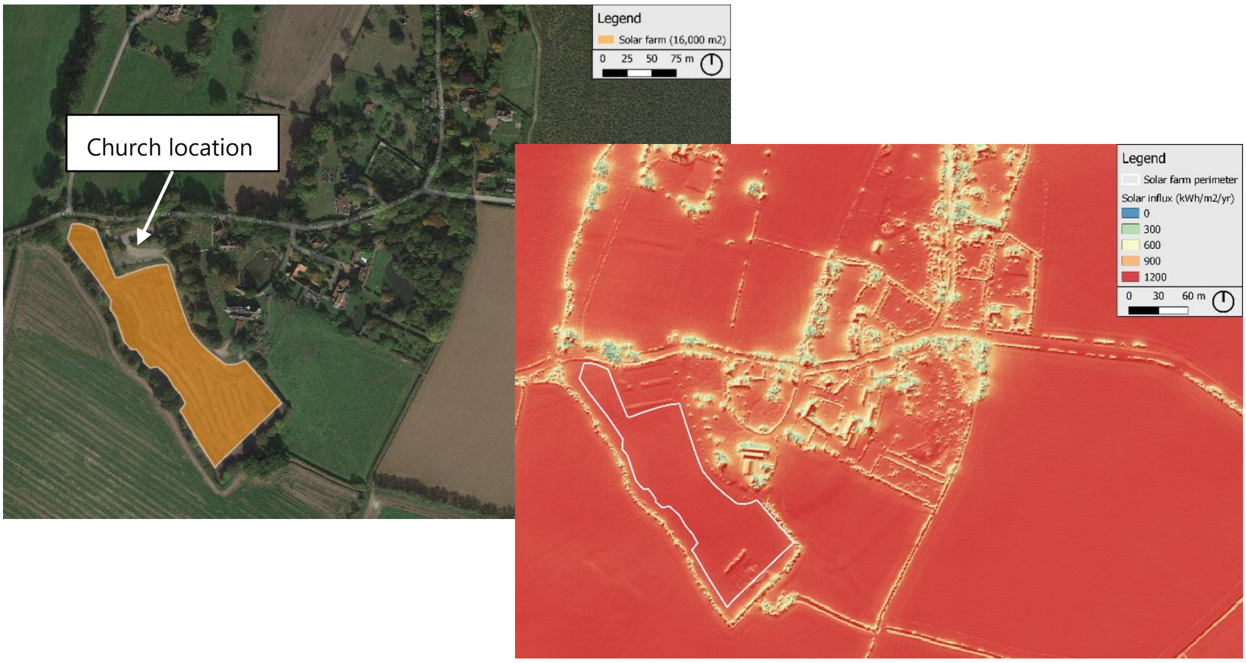

Figure 8—7 Proposed solar farm site for Barocmbe Church and solar energy data. Modelling of solar resource is carried out in QGIS using the UMEP SEBE tool, with meteorological data from PV-GIS.

Innovations in Barcombe will include incorporating a number of heat sources including the development of a rural community 'micro' 5th generation heat network which will integrate heat pumps where resource and land is available and distribute heat to other properties. Additionally, the renewable generation will be managed through the smart micro grid to focus on community energy requirements and local load management including heat and transport to reduce capacity requirements on the DNO. DSO interfaces will be developed to provide valuable insight on how a DSO can benefit from the flexibility of such a scheme and predict demand which can be used to support the development of new DSO operating models.

Areas like Barcombe are typified by only a small portion of buildings being suitable for fabric retrofit, due to their construction and even then, costs may be prohibitive to homeowners. By employing a higher penetration of ground source heat pumps and micro grids, which have a far higher COP (2-4), improving efficiencies of ASHPs and combining with local renewable generation and public e-mobility Barcombe would significantly reduce its peak consumption. This would otherwise increase dramatically with a shift to low carbon transport and more significantly one away from oil as the main source of heat. Reducing peak demand and thus network reinforcement requirements whilst providing sufficient heat to customers in cold winters, is key for keeping the cost down for a UK low carbon transition; as these reinforcement costs will be paid for by consumers.

The Barcombe project will develop a community energy model to address these challenges. It is also determining feasible models that can be applied to achieve the proposed low carbon solutions. Notably for heat solutions will be applicable to the respective location and clustering of buildings and location of heat resource (including water, ground and air source heat pumps) and understand how heat sharing and integration into the development of local renewable generation can be achieved and be commercially viable. Having a detailed and precisely informed strategy is vital for making such challenging schemes viable.

8.3.3 Delivery model

The project is at the time of writing in the final stages of achieving Network Innovation Competition funding to progress the project, where it would partner with UKPN. Barcombe already has a very active community group and is pursuing a bond model. The community has already been successful in raising money for a community fund which it is looking to invest in low carbon solutions.

8.3.4 Scalability

There are multiple similar off gas grid rural communities in Greater Brighton where similar technologies and delivery models to those being explored in Barcombe would apply. These include Plumpton, Firle (which is currently pursuing a 5th generation heat network and solar farm), and Cooksbridge – to name three in close proximity to Barcombe. In the UK context a recent report commissioned by BEIS concluded that for a 1-in-20 winter scenario for off gas grid communities, 30% of low voltage feeders would need upgrading to provide low carbon heat (generally heat pump based). Even with these upgrades as little as 41% properties would have sufficient heating (based on ASHPs). This is a significant issue as there are currently 4 million households off the gas grid in the UK which would likely rely on electrification of heat in order to make it low carbon (as the hydrogen model for heat depends on utilising the existing gas network).

8.4 Crawley integrated system consideration

Similarly to Newhaven, Crawley represents an area with many opportunities but they have not been joined together into one overarching energy strategy. Rather than to provide a detailed project breakdown this case study is to highlight the significance of taking a wider perspective. As the projects and opportunities identified in Crawley do not seem to have been tied together into an over-arching strategy. The main opportunities and projects currently existing in Crawley are highlighted in Figure 8—8.

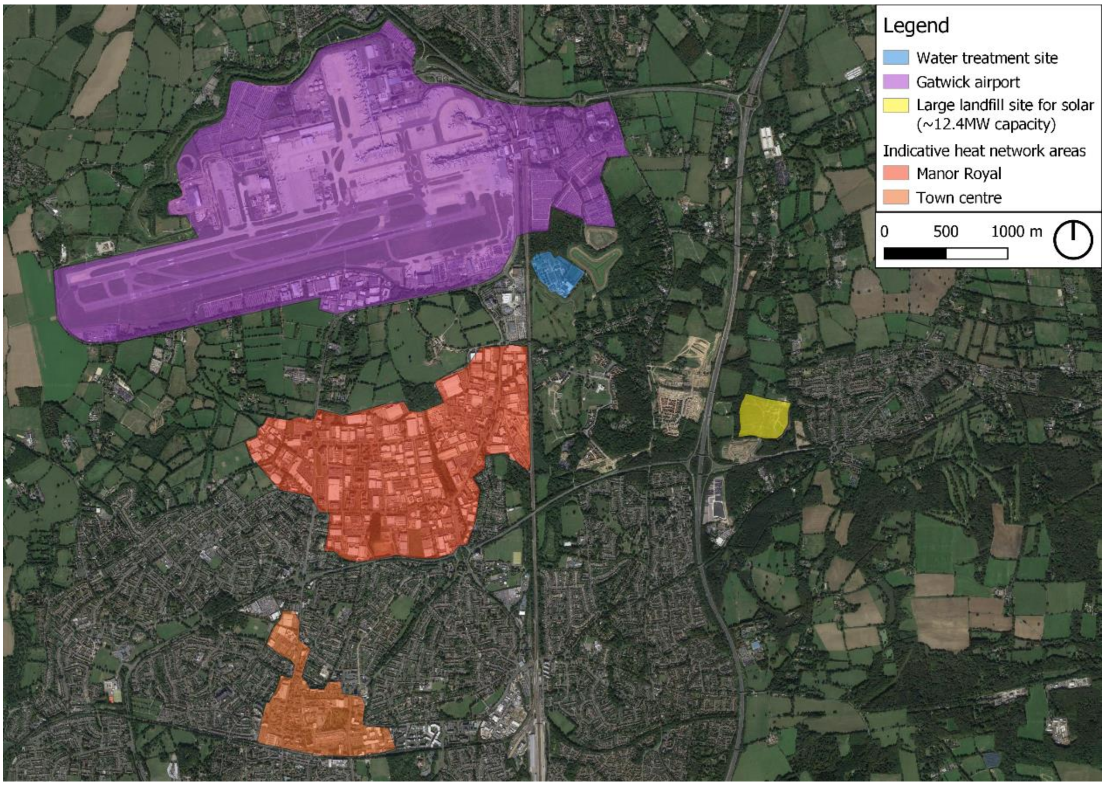

Figure 8—8 Map of the Crawley area, with key sites identified.

The town centre has a proposed heat network as does the Manor Royal business park to the north of the town. However, these two projects do not appear to have been linked into one heat network strategy for the area. For example there could be an opportunity to connect the two networks together, potentially unlocking better economic opportunities. Gatwick is the largest single point emitter of carbon in the Greater Brighton area, even when excluding aviation, and is identified as central by the Coast to Capital for economic growth and in the region. Whilst it has its own highly developed strategy it is important to integrate this into the local area’s decarbonisation strategy.

The Manor Royal business park is supported by the BISEPS Interreg project and ongoing studies of the site have identified numerous low carbon opportunities. These should be integrated into a wider local approach to decarbonisation to fully realise their benefits. These opportunities include, solar PV, CHP, fuel cells, heat pumps, PV and battery and solar car ports. The latter point in particular, as with all transport projects is important to integrate into a wider mobility model to fully understand charging usage and requirements.

Being a major international, national and local transport hub transport issues are key in this area and any low carbon transport projects in such a significant transport hub should naturally become viewed as exemplar projects. The major railway line running through the area would be worth investigating if it is suitable for a Riding Sunbeams project. Similarly, the location would be suited to electric vehicle hubs due to its significance from a wider transport perspective. At Gatwick smart charging options are being explored, as part of their wider EV strategy. As technology and scale of EV deployment progresses there are many opportunities; for example, long stay electric vehicles could be treated as batteries for the airport to be drawn on. Smart ticketing systems would allow this to function as they could ensure cars would be fully charged once they were collected. This would also help achieve value form charge points during long stays, where they will otherwise be an unutilised asset.

Gatwick Airport is currently pioneering hydrogen transport with the eighth hydrogen fuelling station in the UK opening there in October 2019. The hydrogen is produced onsite via electrolysis and is part of the pan-European H2ME2 project. Crawley is located within 20km of the potential low carbon transport hub at Bolney (described in Section 8.1), which is significant when the area is transitioning to hydrogen with 20 new hydrogen buses being procured for the area.

Two potentially useful energy assets were identified in the initial assessment of Crawley. The first is the water treatment plant near to the airport. Discussions with southern water suggest most facilities such as these have waste heat, which could be utilised within heat networks. The second is the large landfill site to the east of Crawley. As mentioned previously, utilisation of such sites for solar is seen as a priority from the tri-LEP studies. The site in question has a footprint large enough for a 12.4MW solar farm that could be expected to generate over 13GWh/yr (this site falls just inside Mid Sussex rather than Crawley Local Authority – but Crawley is where the power would likely be utilised). A sleeving arrangement could be put in place to utilise this solar power within Gatwick, realising higher revenue for the solar farm than would be achieved by selling to the grid and lower than grid price electricity for Gatwick – which would be of particular value low carbon transport charging.

A key theme from most of the case studies presented, notably Crawley, Barcombe and Newhaven is that in one geographic area there are multiple low carbon options in one area. Given that the aim of this energy plan is to help enable an entire energy system transition this is to be expected, however, what it demonstrates is that considering different vectors in isolation means the most effective means of achieving this transition is missed.

8.5 Haywards Heath train station – solar car parks

This section examines a solar car park/EV charging hub in the context of a busy commuter train station. It assesses stand alone PV and battery integration, and different tariff rates; arriving at some initial optimal savings and payback rates (a detailed feasibility study is required for full assessment).

8.5.1 Introduction

The Action Plan provided by the three LEPs identifies car parks as ideal locations for renewable energy generation projects. They provide a great opportunity for the innovative integration of solar PV in the form of solar carports, battery storage and electric vehicle charge-points. In this way, the electric mobility transition can be supported with clean energy generated in a decentralised fashion and through a highly visible carbon reduction initiative. The financial viability of this project is now explored through a pre-feasibility study of a solar carport in the Haywards Heath Station Car Park. As observed in Figure 8—9, there is extensive roof space available on the train station (~1200 m^2) and the possibility to cover the top floor of the new multi-storey car park (~5600 m^2) with a solar carport, which justify investment in a PV rooftop installation.

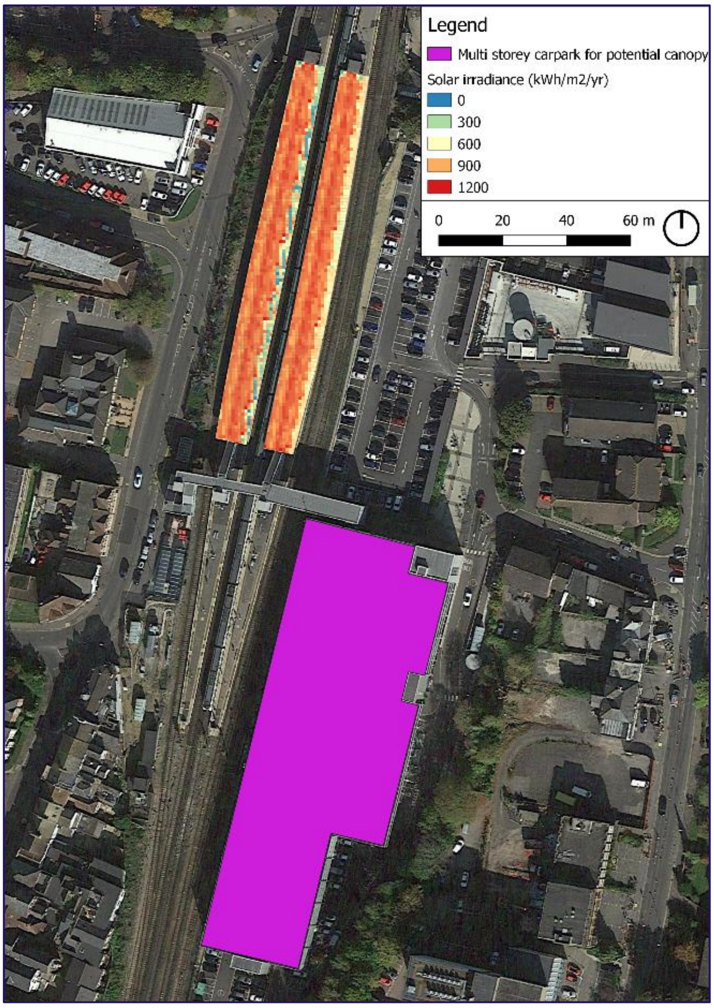

Figure 8—9 Map of Haywards Heath train station car park and rooftop solar modelling for the train station.

This is assessed in a near-future (2025) context of significant EV uptake trends, dictated by the UK government's objective of 50 to 70% EV share of new car sales by 2030 (Department of Transport, 2018). This justifies the installation of dedicated charge-points in part of the car park's parking spaces. Centralised battery storage is also considered for the energy management of the intermittent generation of PV electricity and the maximisation of its value for EV charging demands. An extent of energy arbitrage is also assumed, mainly to provide cheap electricity for EV charging when the generation of the PV modules is not sufficient.

8.5.2 Project Details and Assumptions

Given the uncertainty regarding future EV charging demands and the potential revenues available to commercial batteries as a result of regulatory uncertainty in the market of behind-the-meter installations, very general assumptions are made to produce a simplified techno-economic model of the solar carport energy system, which however is still able to provide useful insights into its economic performance.

The daily parking availability throughout the week is obtained from data gathered by the car park operator Saba (Saba Parking, 2019). An example of the average hourly trend on Tuesdays is shown in Figure 8—10. During the week, the data shows that the car park essentially fills up by 8-9 am there are virtually no free parking spaces until 4-5 pm.

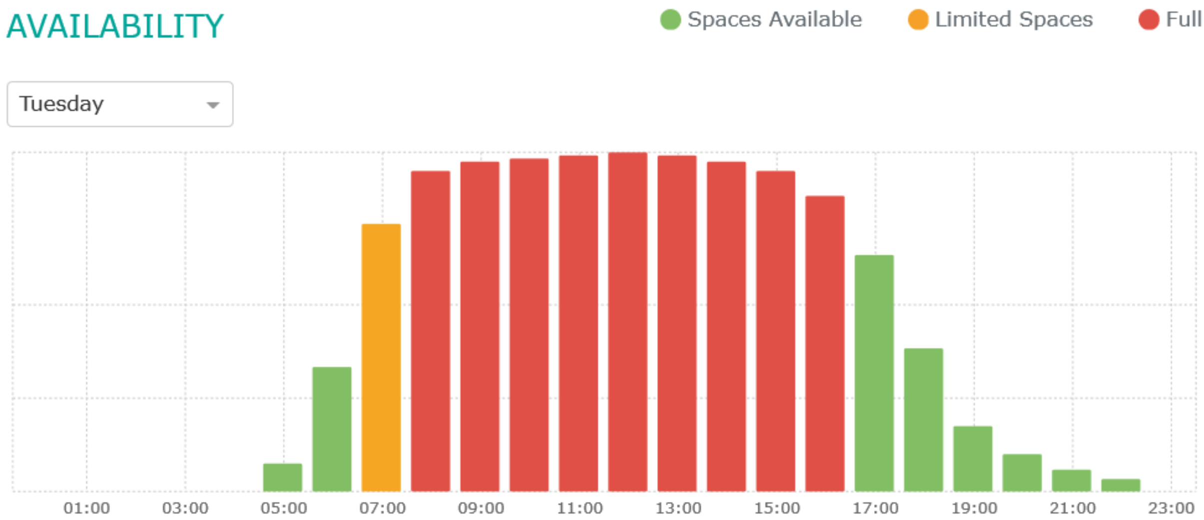

Figure 8—10 Hourly parking availability on Tuesdays in the Haywards Heath Station Car Park (Saba Parking, 2019)

On Fridays, Saturdays and Sundays the trend shown in Figure 8—10 is gradually less prominent, with more than 80% of spaces available throughout the day on Sundays. Two major utilisation patterns of the car park are noticeable:

1. The majority of the car park customers park for a good proportion of the day and take the train to a distant location, most probably in the London area where the congestion zone charge and limited parking space would not encourage them to drive there.
2. A proportion of the spaces are leased to local businesses. These would be similarly occupied by one vehicle for the majority of the day.

Since most of the customers remain parked for the majority of the working day (9-17 h), it can be largely assumed that in the case that a parking space is occupied in a given day, the vehicle remains parked for the rest of the day. The average occupancy factor throughout each day of the week is then taken from the maximum occupancy peak observed in the monitoring data. This results in the average number of parked cars shown in Table 8—2.

Table 8—2 Average number of parked cars in the Haywards Heath Station Car Park by day of the week

	Monday to Thursday	Friday	Saturday	Sunday
Average number of parked cars	826	628	231	83

Table 8—3 below summarises the major assumptions regarding the formulation of the techno-economic model, subdivided by the part of the system to which they refer: the EV charging infrastructure, the solar PV modules or the centralised battery storage.

Table 8—3 Details of key assumptions used in modelling.

Detail	Assumption	Justification
		EVs charging
EV average daily mileage	36 km	The Department of Transport uses a corresponding average annual mileage of 13,200 km for EV policy design (Dodson & Slater, 2019)
EV charge points allocation (2025)	20% of total parking spaces	In the most recent EV charging policy consultation, the UK government has proposed to allocate one in five parking spaces to be converted into an EV chargepoint by 2025 (Department of Transport, 2019).

EV average charge	4 kWh	It is assumed the average EV user would have charged up their vehicle overnight. Therefore, when he/she parks in the car park, the EV battery has been discharged for half of the average daily vehicle commute (18-20 km), which corresponds to 4 kWh.
EV chargepoint type & cost	Fast charger (7 kW) - £2,000 – £2,500	This type of charging power is suitable for the relatively long stays of the customers. The EV average charge can be provided in a little more than half an hour.
	Solar PV	
Average summer / winter capacity factor	18.4% / 6.54%	These values are specifically produced for the Haywards Heath location through simulations of the hourly power output of comparable solar PV installations (10% system losses) from renewables.ninja.com
PV module power density	0.15 kWp/m^2	(Lazard, 2019a)
Solar carport CAPEX	1400 £/kW	https://www.energymanagermagazine.co.uk/nottingham-taking-the-lead-in-solar-carports/
Solar carport OPEX	16 £/kW-yr	(Tjengdrawira, Richter, & Theologitis, 2016)
PV lifetime	25 years	(Lazard, 2019a)
	Centralised battery storage	
Battery CAPEX	350 £/kWh	(Lazard, 2019b) – also taking into account 2025 battery pack cost reductions predicted by (Curry, 2017).
Battery OPEX	11 £/kWh	(Lazard, 2019b)
Battery lifetime	20 years	(Lazard, 2019b)
Round trip efficiency	90%	(Mariaud, Acha, Ekins-Daukes, Shah, & Markides, 2017)
Min/ max SOC	15%/ 90%	(Mariaud et al., 2017)

The techno-economic analysis assumes electricity balances on a daily timeframe, with a differentiation between the summer and winter PV production loads. The entire daily PV electricity production is assumed to be available for EV charging regardless of the hourly resolution of the supply and demand trends because EV loads are deferrable, given the relatively long parking time of the vehicles as described earlier. In this way, solar PV utilisation can be maximised through an assumed smart charging protocol of the charge-points. The daily EV charging demands are derived with the following equation:

$$\begin{aligned} &\mathit{Daily\ EV\ charging\ demand} \\ &\quad = \mathit{EV\ average\ charge} \times \mathit{EV\ chargepoint\ share\ of\ parking\ spaces} \times \mathit{daily\ number\ of\ parked\ cars} \end{aligned}$$

This corresponds to an average charge point utilisation of one car per day when the car park is full, which could be considered a conservative assumption. A 1.05 factor is applied to the winter EV loads as the performance of the batteries worsens in colder temperatures.

8.5.3 Business Model & Revenue Streams

Two business models based on the solar carport infrastructure with and without centralised battery storage are analysed. The principal revenue stream of solar carports is understandably the sale of electricity to the parked EV users. Even though several businesses with public car parks, such as supermarkets currently offer free fast charging. This is based on the need to attract/support early EV adopters. In 2025, this is unlikely to be viable/necessary and therefore a charge per kWh purchased is assumed, with no connection charge. A low and a high price, both in the range between standard home charging tariffs and rapid charging tariffs, are assumed for the analysis (see Table 8—4). A potential business model would entail the establishment of EV clubs, which enable discounted or exclusive use of EVCPs through a monthly or yearly membership subscription. This could be a possibility if EV customer charging trends for the specific site lead to a reasonable average cost per kWh of EV charging.

In the absence of battery storage, any daily excess of solar PV is sold instantaneously to the grid through the Smart Export Guarantee (SEG) at a particularly low tariff given the off-peak timing (current estimates are at £0.04 – £0.05 per kWh). On the other hand, if the daily EV demand is greater than the daily PV production, electricity is purchased at a standard midday tariff price to be used instantaneously for the EV charging demand. With centralised battery storage, the sale of excess PV electricity and the purchase of grid electricity can be time-shifted in order to obtain the most convenient rates, which correspond respectively to the peak evening period (16:30 to 18:30) and the overnight off-peak period (00:30 to 4:30). In order to maximise the revenue potential of the battery, it is assumed that every night it is charged to its maximum SOC, allowing for capacity of excess PV generation the next day. This is then discharged to its minimum SOC through EV demand balance and the sale of remaining capacity at peak time either to a third party through a PPA or to the grid, assuming greater access for behind-the-meter small-scale storage in 2025. Energy arbitrage strategies are dependent on the real-time grid electricity price predictions, unique to each different day. For the purpose of this simplified case study, constant average tariffs are assumed for the relevant periods of the day and the same strategy of selling all surplus electricity after balancing all EV loads is then proposed.

As the focus of the case study is the maximisation of the value of the solar resource in car park locations, the centralised battery is sized according to this objective and therefore the energy arbitrage service is secondary:

- For relatively small PV installations that mostly require the import of grid electricity to satisfy the EV loads, particularly in winter as a result of the reduced solar resource, the battery is sized to provide this deficit from cheap overnight grid electricity.
- For larger PV installations that mostly balance the EV loads with the locally produced electricity, the battery is sized to store this excess and sell it during the peak system time.

Historic data of Octopus Energy agile tariff are used as a reference for the determination of the peak sale and overnight purchase electricity tariffs. A high and low value is assumed for each, in order to understand the effect of the spread of these tariffs on the financial viability of the solar PV and battery storage business case. All the electricity tariff rates are indicated in Table 8—4.

Table 8—4 Average summer and winter electricity tariff rates used for the techno-economic model (Octopus Energy, 2019; pod Point, 2019)

Electricity tariffs	Range	Average summer rate (£ per kWh)	Average winter rate (£ per kWh)
EV charging	Low	0.14	0.14
	High	0.18	0.18
PV day (8 -16 h) sale	Standard	0.04	0.04
Day (8 -16 h) purchase	Standard	0.13	0.14

Peak (16:30 – 18:30) sale	Low	0.12	0.13
	High	0.16	0.18
Overnight (00:30 – 4:30) purchase	Low	0.08	0.08
	High	0.10	0.10

8.5.4 Financial Viability

Figure 8—11, Figure 8—12 and Figure 8—13 illustrate the annual cashflows (including annualised capital costs) resulting from investments in a PV-only solar carport and a solar carport coupled with centralised battery storage for the different ranges of PV deployment in the car park. Project payback periods to recoup the capital investments are also indicated, assuming the annual cashflow for this specific year of activity remains constant throughout the project lifetime. The investment necessary for the installation of fast chargers in 20% of the parking spaces (between £330,000 and £420,000) is omitted from the cashflow calculation as it is assumed it is covered by the infrastructure group or government's Charging Infrastructure Investment Fund.

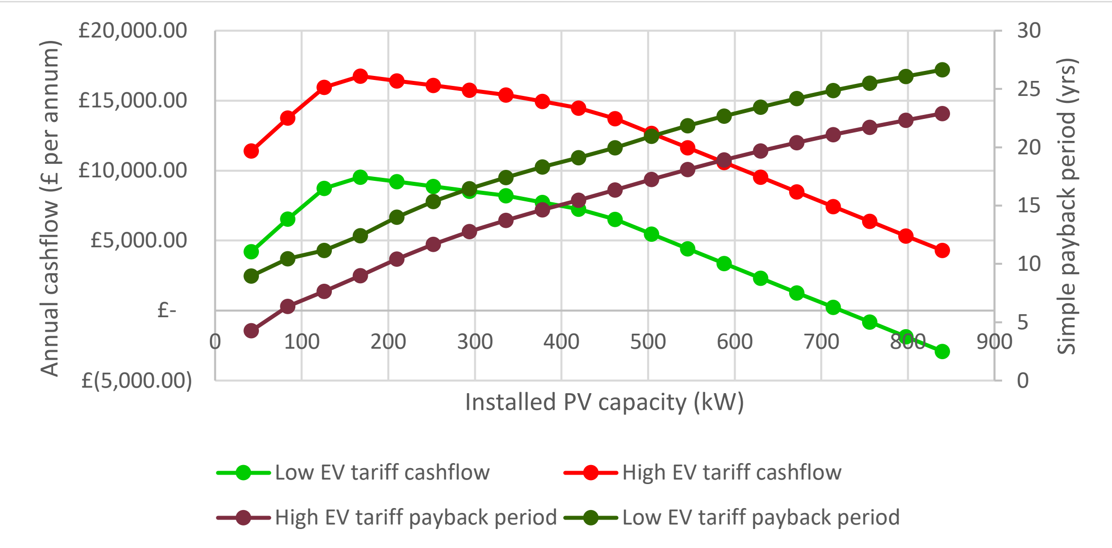

Figure 8—11 Annual cashflow and payback period comparison of PV-only solar carport systems at different installed capacities.

Figure 8—11 illustrates the trade-off between the size of the PV solar carport system and the financial viability of such project. At both low and high EV tariff charged, maximum cashflows between £9,700 and £16,900 are reached at installed capacities of 149 kWp in both scenarios. Past this solar PV capacity it is less cost-effective to balance residual EV loads with additional PV capacity than purchasing the required demand directly from the grid at the midday tariff assumed. The additional investment required does not justify the additional revenue from the EV charging sales. In addition, during the days with lower EV demand, any surplus PV electricity is exported at the SEG tariff, which has relatively low value. At the optimal PV size of 149 kW, the investments require relatively long payback periods between 8.3 and 11.6 years, attesting to the capital-intensive nature of the investment.

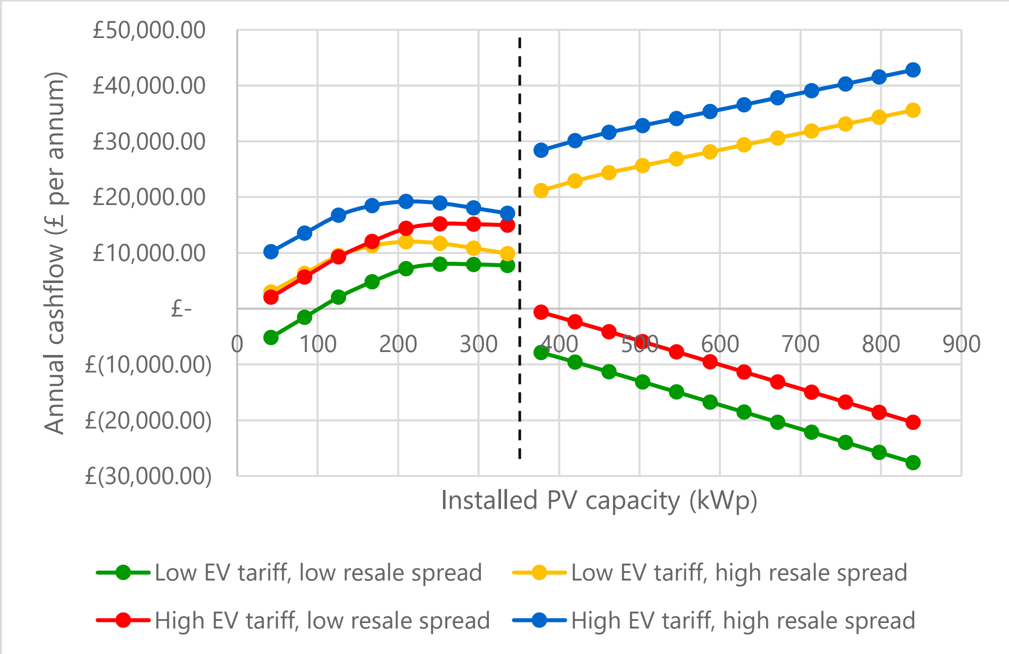

Figure 8—12 Annual cashflow of solar carport system with centralised battery storage at different installed PV capacities.

For the cashflow and payback analysis of the PV-battery hybrid system in Figure 8—12 and Figure 8—13respectively, four different tariff scenarios are presented using the tariff data from Table 8—4:

1. Low EV tariff, low resale spread – a low EV charging tariff is applied, along with an unfavourable electricity resale spread as it is assumed overnight electricity is purchased at an average high rate and surplus electricity is sold at an average low rate. Given these unfavourable revenue characteristics, the project payback periods are extremely long (mostly over 20 years) and the annual cashflow is positive only for solar PV systems that need a relatively small capacity battery system to balance the energy deficit for the required EV demand. When compared to the project economics of the PV-only carport, the hybrid battery-PV carport performs poorly and the investment in a battery system is not justified.
2. High EV tariff, low resale spread – this scenario differs from the previous one only in the EV tariff charged, which is in the high range. Despite this, the annual cashflow and payback period trends are similar to those of the prior EV tariff scenario; the main difference is that the payback period is reduced significantly for each solar PV size given the additional inflow of EV charging revenue. However, this scenario still performs worse than the corresponding PV-only, high EV tariff scenario.
3. Low EV tariff, high resale spread – the high resale spread reflects a low overnight electricity purchase rate and a high peak sale rate, hypothetically achieved with a more effective energy arbitrage strategy. This increases massively the annual cashflow values in Figure 8—12, outperforming the solar-only carport systems. Payback periods of all hybrid systems are also reduced below 18 years.
4. High EV tariff, high resale spread – this scenario is identical to the previous one, the only difference being that high EV tariffs are charged, therefore securing a higher total revenue. As a result, project payback periods are additionally reduced and annual cashflows receive a boost.

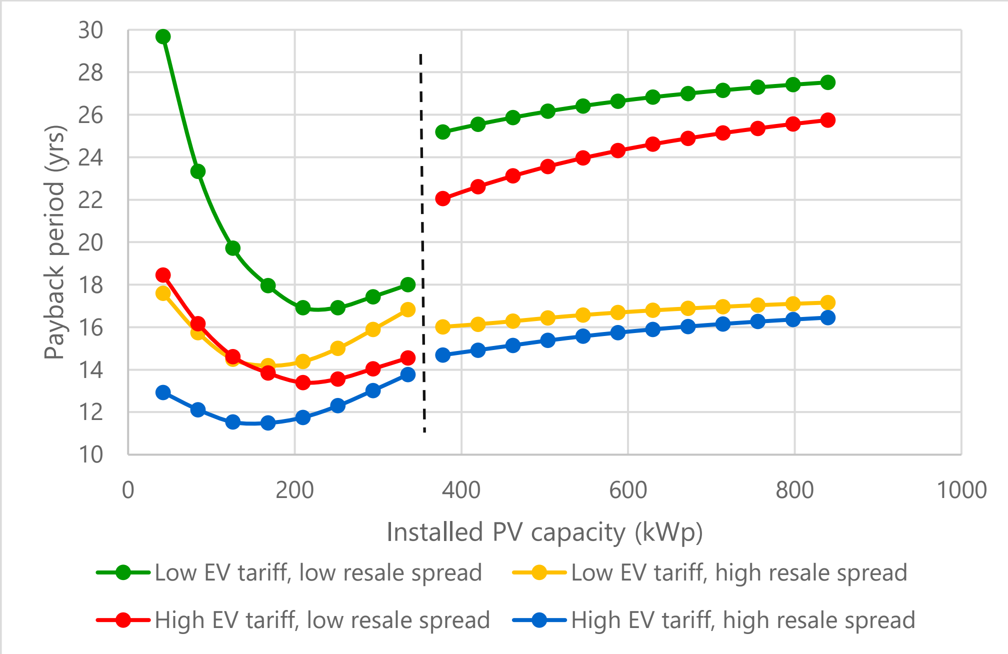

Figure 8—13 Payback period solar carport system with centralised battery storage at different installed PV capacities.

8.5.5 Scalability

The financial viability analysis demonstrates that the additional revenue that a battery system can potentially attract with successful energy arbitrage measures in a PV-battery hybrid solar carport system is able to make the additional investment worthwhile. The main drawback is that high electricity tariff spreads would most likely come with high risk profiles. In the scenarios where grid electricity arbitrage does not bring about significant revenue, it is mostly the case that investment into a battery system is not rapidly recouped solely based on the additional revenue from the arbitrage of the electricity produced from the solar carport. In conclusion, at the predicted 20% EV market share in 2025, solar carport projects represent an attractive decarbonisation initiative with the potential to bring value to an extensive commuter base; however, centralised storage implementation should be accurately assessed and additional arbitrage or demand-side management revenue opportunities should be explored. To this end, the future value stream of distribution network referral that batteries can bring about could play a role.

There are multiple locations which could incorporate similar strategies to Haywards Heath, some examples being Lewes, Worthing, Three Bridges and Burgess Hill. Although the scale of projects will vary the same principles apply. The sites suggested are for train stations, but the findings are analogous to other car park applications, so long as there are not resource issues due to factors like shading.

8.6 Riding Sunbeams

Riding Sunbeams is a company which is developing solar farms to feed directly into the rail traction system. This section explores the technical detail behind the project, business models and projects in Greater Brighton.

8.6.1 Introduction

The Tri-LEP Action Plan identifies solar PV installations for Network Rail, a major regional energy consumer, as a key renewable energy generation project model. With the heavily congested Sussex and Wessex dc rail network routes, the Greater Brighton region provides unique integration opportunities for solar farms, due to relatively high solar irradiance levels compared to the rest of the UK and highly congested electricity distribution networks. Following a high level audit of land use constraints from Community Energy South around the electrified rail infrastructure in the Southern Region area, around three quarters of the traction power substations should be able to accommodate an intermittent supply of around 1MWp solar array in lineside developments (South East Local Enterprise Partnerships, Coast to Capital, & Enterprise M3, n.d.). As a result, the local distribution networks would not bear any of the extra renewable energy generation capacity, while Network Rail would be able to source increasing proportions of electricity from renewable sources at a competitive price, to feed directly into the third rail for traction power.

8.6.2 Technical Details

The social enterprise Riding Sunbeams is a joint venture between the charity 10:10 Climate Action and the organisation Community Energy South that has made significant progress into delivering these types of projects. In 2017, they carried out a technical feasibility study along with researchers from Energy Futures Lab at Imperial College London and electrical engineering specialists Turbo Power Systems to assess if solar PV integration into third rail direct current is commercially viable. Following consultations with Network Rail engineers to refine the technical solution, the main outcomes are the following:

- The connection of solar PV arrays can be economically established through the conventional AC feeder systems that carry grid electricity to the substations, by using conventional DC-to-AC converters and ancillaries (Murray & Pendered, 2019).
- One of the major technical challenges is balancing the intermittency of both solar PV generation and the trains' traction power demand. However, since each grid supply point (GSP) supplies around ten to fifteen substations at an average 2-8 km apart, the DC traction power supplied by the hypothetical solar array would be shared across all of these and consequently all the electrified trains through the route, reducing significantly the intermittency component at the supply end (Murray & Pendered, 2019). This connection setup would prevent additional investment into storage assets, which could compromise the financial viability of the project given its low competitiveness in a strictly energy management model.
- The connection setup does not cause operational risks around possible dc voltage range exceedances on the tracks nor power quality issues on the DC supplies (Murray & Pendered, 2019).

8.6.3 Business model

The Riding Sunbeams consortium started thinking about this disruptive project model when developing a community owned solar farm in Balcombe, Sussex which unfortunately could not be connected to the distribution network without an expensive upgrade. In the absence of any other potential purchasers, they approached National Rail, which have explicitly targeted direct supply of renewable traction power as a priority for Control Period 6 (2019-2024) (Murray & Bottrell, 2017). Community-owned solar PV purchased through a "private wire" PPA remains the most viable business model. Table 8-5 illustrates some key financial indicators of this type of business model, based on actual cost data from the current project pipeline and estimated price and volumes of energy purchased from Riding Sunbeams' progress reports. These show potential advantages over the current business-as-usual National Rail grid power contracts:

- Solar arrays above a minimum peak power capacity of 1MWp would be able to offer unsubsidized LCOE prices competitive with the current grid electricity costs paid by National Rail, as observed in Table 8—5.

Future cost trends demonstrate that this gap is expected to widen in the future. In addition, the significant array size would justify the capital raising process necessary for fixed development and connection costs of the project (Murray & Bottrell, 2017).

- Traction power makes up around 10% of the National Rail operational costs and therefore pursuing these "green" energy PPAs would help them reduce rail operating costs and carbon emissions, as their electricity traction costs would effectively be frozen in the long-term (Murray & Bottrell, 2017).
- Even though profit margins for this community-owned solar traction farm portfolio are relatively modest (see Table 8—5), they are sufficient to underwrite crowdfunded investment, and to generate surplus for community benefit funds (Murray & Pendered, 2019). This could in turn be used for further renewable energy or energy efficiency projects, feeding into a sustainable cycle.

Table 8—5 Key financial indicators of community-owned, utility-scale solar PV projects with a "private wire" PPA in place with National Rail (Assumptions: capacity factor of 12-14%, 55 – 85% of annual PV production sold through the PPA to NR at competitive per-kWh-prices, remaining is sold to third parties or grid through SEG scheme at reduced per-kWh-price) (Lazard, 2019; Murray & Bottrell, 2017; Murray & Pendered, 2019)

Grid electricity LCOE (£ kWh^{-1})	Utility-scale solar PV LCOE (£ kWh^{-1})	Utility-scale solar PV CAPEX (£ kWp^{-1})	Utility-scale solar PV OPEX (£ kWp^{-1} yr^{-1})	Profit margin (£ kWp^{-1} yr^{-1})	Simple payback period (yrs)
0.070 – 0.090	0.050 – 0.116	£1,000 - £1,200	£9 - £13	£5 - £55	10 - 30

Riding Sunbeams's intentions are to exploit the social involvement component of this business development model even further, by inviting commuters and railway workers to get actively involved with lineside communities in these crowdfunding-style projects.

8.6.4 Project Pipeline

From Riding Sunbeams feasibility study and the prior business case considerations, the project model is feasible from the technical point of view and viable from the commercial point of view. At the beginning of 2018, Riding Sunbeams identified the first solar traction farm project opportunities in the south of England by engaging with established community energy groups and National Rail and submitted a portfolio bid to the government's Rural Community Energy Fund. Having won it, they could fund full, site-specific feasibility studies for six pilot projects, of which three are in the Greater Brighton region (Murray & Pendered, 2019). The relevant project details are indicated in Table 8—6.

Table 8—6 Pilot solar traction farm projects in the Greater Brighton region (Murray & Pendered, 2019)**. The bracketed solar array and capital investment required values are from questionnaire feedback rather than the Riding Sunbeams Before Dawn report.**

Project location	Solar array size (MW)	Capital Investment required (£ million)	Funding community energy group	Predicted carbon savings (tonnes CO_2 yr^{-1})
Balcombe	11 (10)	N/A (£10)	Repower Balcombe	3214
Hassocks	3.8 (1)	N/A (£1)	HKD Energy	321
Brighton and Hove	3.6	N/A	Brighton and Hove Energy Services Coop	1157

The locations of the three Greater Brighton Riding Sunbeams projects are displayed below in Figure 8—14.

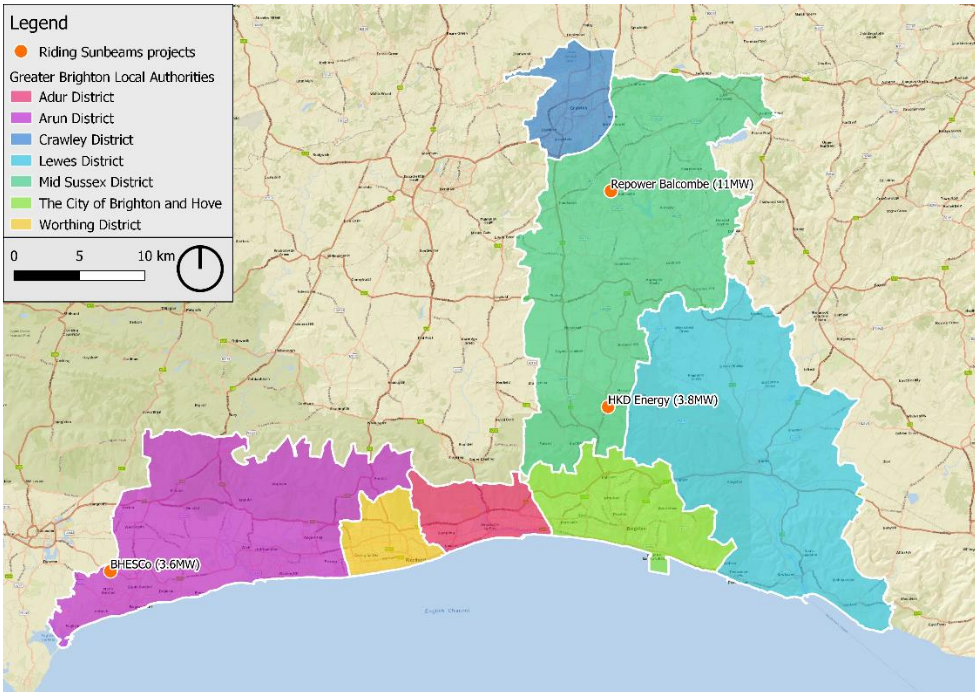

Figure 8—14 Riding Sunbeams projects in Greater Brighton.

Before progressing with the six full-scale projects, a demonstrator trial is being implemented since August 2019 along the railway line between London and Weymouth, at the Aldershot substation. With funding from the Department for Transport and Innovate UK, 135 solar PV panels with a total peak power capacity of 37 kWp were designed, installed and connected to the substation to an ancillary transformer on the traction system to supply power to lights and signalling equipment (Wordsworth, 2019). By monitoring demand loads, generation capacity and the quality of supply, the modelling and commercial delivery models used in the feasibility studies will be validated and tested for the much larger volumes of solar power planned for the pilot solar farms. At the current progress, the first community solar traction farms could connect to UK railways in 2020 (Murray & Pendered, 2019).

8.6.5 Scalability

According to the South East Local Enterprise Partnerships, Network Rail are the single biggest unregulated consumer of electricity in the UK, procuring around 3.2TWh per year . They have detailed in their corporate strategy ambitions to source increasing proportions of their traction and non-traction power demand from renewable energy sources and they can do so at competitive prices from these community-owned solar projects. Deployment at scale could plausibly shave around 4% off the Southern Region's traction electricity bill - and 13% off the associated carbon emissions (Murray & Pendered, 2019). For community energy groups in the Greater Brighton region, this represents an attractive market between £0.6m and £2m per year, which corresponds to roughly 0.8 - 2% of the Southern Region's total traction electricity demand. Once the first solar traction farms pipeline is delivered within the next five years and their financial viability demonstrated on a full-scale, the successive phase rollout will benefit from economies of scale and a greater understanding of the technical requirements of renewable energy grid connection to the third rail for traction power.

9 Solar roadmap

This is meant to act as a section which can be stand alone and as such contains information which is repeated in the report.

9.1 Introduction

The Greater Brighton region covers seven different Local Authority (LA) areas in south east England and is home to over 900,000 people, 400,000 jobs and 40,000 businesses. The extent of the region and the Local Authorities are displayed in Figure 9—1.

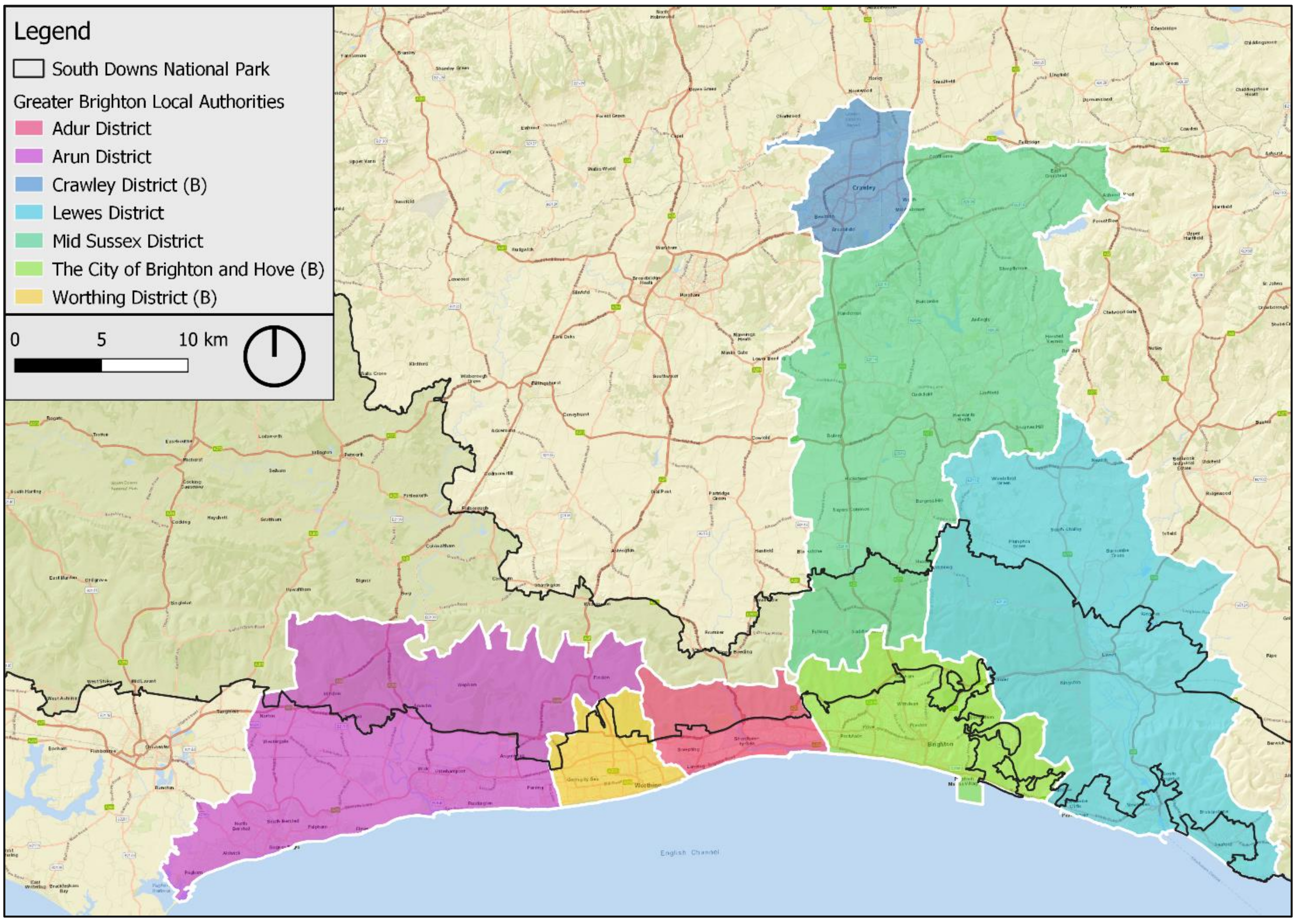

Figure 9—1 The Greater Brighton area. The background map is the ESRI standard baselayer.

As the map indicates there is a substantial variation in geography of Greater Brighton; containing urban areas, notably Crawley in addition to Brighton and Hove, as well as rural areas – predominantly in Mid Sussex and Lewes. The area, as shown in Figure 9—1has the South Downs National Park running through it. The impact of this is discussed more in the planning section below but essentially large scale renewable projects within the National Park are less likely to pass through the planning system. However, there is a strong political will in the area to make carbon reductions, with

many of the LAs declaring climates change emergencies – aiming for 'net-zero'[4] wherever possible by 2030. This is more ambitious than the 2019 central UK target of 'net-zero' by 2050, which again marked an increase from the previous 80% carbon reduction by 2050. A review of the historic Greater Brighton Carbon emissions is presented in Figure 9—2.

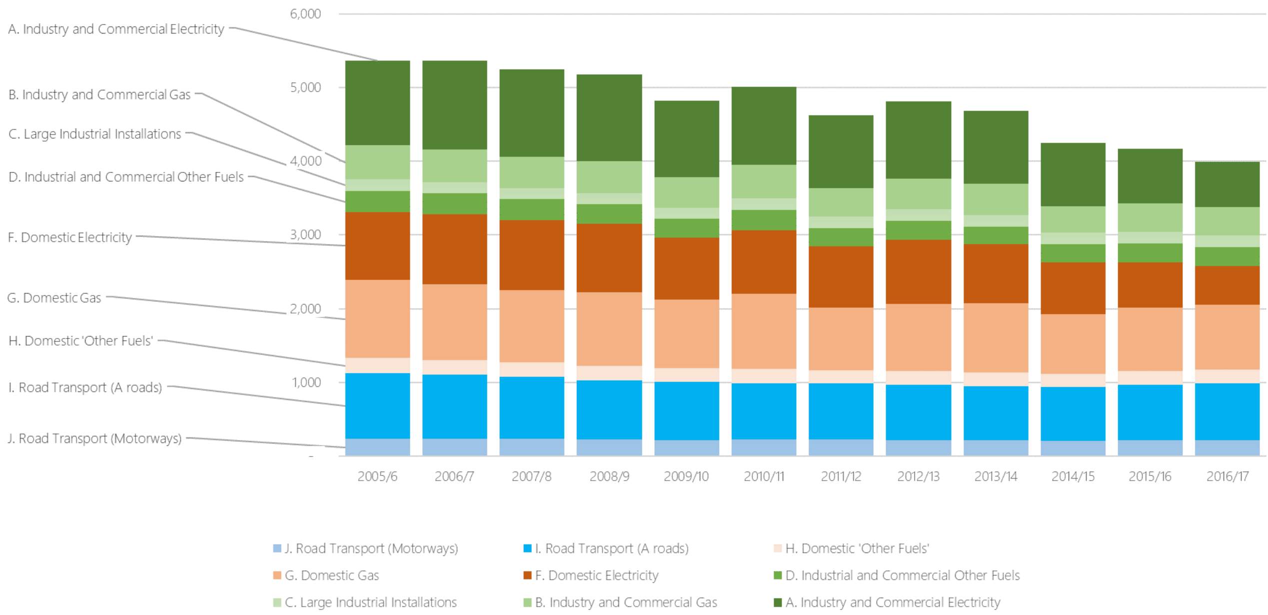

Figure 9—2 Greater Brighton historic carbon emission. Values for emissions are provided in ktCO₂

There is a strong desire to use locally generated renewable electricity, primarily solar, as a first step to bring about these carbon reductions. However, as shown in Figure 9—2 there is a large reduction in the carbon emissions from electricity between 2005/2006 and 2016/2017; making it the smallest share of Greater Brighton's carbon emissions from the three energy vectors of electricity, heat and transport. This is due to the decarbonisation of the UK's national grid, with 46GW of renewable capacity - the largest shares coming from onshore wind (~14GW), solar (~13.5GW) and offshore wind (~9GW)[5]. This grid decarbonisation means that any solar capacity added in the region which is fed into the grid will have a relatively low impact on the area's carbon targets, with benefits instead being captured at the national level. Furthermore, historic trends show that the electricity sector is rapidly decarbonising in the UK, so to be of most value solar projects should assist with the transition to low carbon technologies in the heat and transport sectors. Thus particular attention is given in this road map to solar applications which assist with these aspects of the energy system.

[4] 'Net-zero' refers to an overall balance of zero carbon emissions, so in addition to switching to low carbon energy and materials carbon be offset through carbon sequesting environments and projects – such as tree planting.
[5] BEIS, 2019: UK renewables April-Rune 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/835114/Renewables_September_2019.pdf

Despite solar making up a nearly equal portion of installed capacity in the UK to onshore wind it has a lower capacity factor meaning onshore wind generates more electricity, e.g. during a relatively optimal quarter (April-June 2019) for solar and sub optimal for wind in the UK onshore wind produced 6.1TWh compared to 4.9TWh from solar. Despite a lower capacity factor solar power can still be competitive with onshore wind due to lower local environmental and visual impacts, easier planning permission, efficient small scale devices, greater number of suitable sites, and easier power to utilise on site[6]. Solar is also seen as an empowering technology where individuals, communities, businesses and local government can easily engage. There has, however, recently been some changes in the UK support framework for solar power.

9.2 Technology review

This section provides a brief review of major solar technologies, the overall UK position on them and an indication of costs.

9.2.1 Crystalline Silicon Photovoltaics

Crystalline silicon (c-Si) is the most mature and widely used PV technology and represents 85-90% of the global market (IEA). c-Si continues to dominate the domestic market in the UK with around 90% of the market share, this is split between mono-crystalline (mc-Si) and polycrystalline materials (pc-Si). Crystalline modules are reliable and have relatively high efficiencies (mc-Si ~15-18%, pc-Si ~12-16%).

The manufacture of the silicon wafers is a very energy intensive process and there are now alternative manufacturing techniques which require less energy but would not benefit from the economies of scale that the more mature manufacturing processes have earned. Silicon is an abundant resource and its supply will not limit the projected further growth.

UK position:

There is currently no manufacturing base for silicon PV cells in the UK, although reclamation manufacturing occurs at Pure Wafer in Swansea, Sharp in Wrexham and Romag in the North East of England. The UK is also actively involved in research into silicon cell manufacture at Loughborough University as well as the National Renewable Energy Centre (NaREC). There is also a micro-electronics facility specialising in PV at Southampton University.

UK costs:

Being the market leader technology, crystalline silicon module types are assumed when quoting benchmark solar PV module prices. These benchmarks fell quite rapidly between 2010 and 2013, and average module prices in the different gigawatt-scale national markets continued falling, with a 35% decline in the UK between 2013 and 2018. In absolute British sterling values, this corresponds to module prices firmly below 0.40 GBP per Wp, depending on the specific module design as observed in Table 9—1.

[6] Wind power from a single small scale wind turbine has a 'lumpy' generation profile, this rapid variability leads to problems with among things frequency control.

Table 9—1 October 2019 crystalline module price index (Source: pvxchange.com)

Module class	Avg module price (2019 GBP per Wp)	Nominal power (Wp)	Design Notes
Bifacial	0.34	N/A	Both sides of bifacial modules harness solar radiation
High efficiency	0.29	>295	Advanced module design (PERC, HJT, n-type, back-contact cells)
All black	0.31	200-330	Black back sheet and frames
Mainstream	0.22	270-290	Standard modules, typically with 60 multicrystalline cells, aluminium frame, white backsheet

9.2.2 Thin Film Photovoltaics

Thin film solar cells consist of one or more thin layers of photovoltaic material on a supporting material such as glass or plastic. Thin films account for ~10-15% of global PV sales. The material and manufacturing costs of this technology are normally lower than other technologies but the efficiency of the modules is lower which therefore requires larger installations. Thin film PV exhibits good low light performance such as diffuse irradiance from cloudy skies. Research suggests that thin films may also perform better at sub-optimal solar angles, these are two issues that the UK faces. Another advantage of thin film PV is an improved temperature coefficient compared to crystalline silicon (0.25% per ºC rise in thin film compared to 0.5% per ºC rise in c-Si).

Thin film technology has a unique design advantage as they are flexible and can be curved, partially transparent and bonded to a variety of materials. The lightweight nature of thin film PV allows for novel design ideas as well as improved aesthetics in buildings that might see traditional panel designs as a barrier for adoption. The most common thin film PV material has been amorphous silicon (a-Si) which has an efficiency of 5-8%, however, the performance of a-Si modules degrades during the first few weeks of operation before stabilising. In recent years a more stable variant that uses micromorph silicon tandem cells has been introduced which is capable of efficiencies up to 10% (UKsolarroadmap).

UK position:

The UK has a strong R&D community in thin film PV. There are already significant supply chain businesses such as Pilkington who specialise in glass optimised to suit a variety of thin-film photovoltaics. The Solar tower in Manchester uses 7,244 80W modules to clad the entire surface of the tower which demonstrates how a large-scale solar installation can be aesthetically designed (UKsolarroadmap).

There is significant UK expertise across all aspects of thin film PV, of particular note is SUPERGEN which involves nine of the UK's top universities and has established a network for PV R&D across academia, industry and finance. SUPERGEN is the UK's only accredited body for the measurement and analysis of PV cells and modules, highlighting their significance to the UK industry.

UK costs:

As a result of the more favourable manufacturing process of thin film PV technologies, average European module prices per Wp have historically been below those of crystalline technologies, despite the lower nominal efficiencies. However, in 2018, it seems high efficiency silicon module prices have become competitive against thin film a-Si modules on a per Wp basis.

9.2.3 Concentrated Solar Power (CSP)

CSP systems generate solar power by using mirrors or lenses to concentrate a large area of solar energy input onto a small area. Electricity is generated when the concentrated light is converted to heat, which drives a heat engine turbine. Heat can be stored in molten-salt storage and used overnight reducing power storage issues for continuous overnight supply. They are generally very large facilities, in the tens to hundreds of MW range.

UK position:

For CSP to function effectively it needs high levels of direct solar radiation. This coupled with cloud cover having a very large impact on performance, relative to PV, means current technology is not currently suited to the UK. The lack of suitability in a Greater Brighton context is enhanced by the scale normally associated with CSP not being suitable for the region.

UK costs:

Average installation costs have fallen from 4,600 – 10,000 £/kW in 2010 down to 2,400 – 5,600 £/kW in 2018. This is still several times higher than PV but includes storage and has a higher capacity factor. This has resulted in CSP being on at least cost parity per Wh with PV in optimal conditions (e.g. Saudi Arabia), however, this would not be achieved in the UK with current technology.

9.2.4 Concentrator PV

Concentrator PV uses an optical concentration system which focuses the suns energy onto small, high-efficiency cells. The technology uses high-quality epitaxial multi-layer structures and is much more complex than thin film or silicon panels as it involves solar tracking (the cells do not generate electricity when the sky is cloudy or the sunlight is not direct) and optical concentration.

UK position:

This is an area that the UK already has strength from an established satellite industry with companies such as Surrey Satellite Technology and IQE Ltd in Cardiff. IQE Ltd is the leading UK manufacturer of high performance multi-junction epitaxial structures. There are UK industry strengths in the sectors required by this technology and the UK has a history of world leading manufacture of III-V semiconductors.

UK costs:

There are currently no concentrator PV installations in the UK yet and deployment is still limited world-wide compared to traditional PV and CSP. CPV costs are currently at ~1800 £/kW.

9.2.5 Solar Thermal

Solar thermal systems can contribute to decarbonising heat, by harnessing the sun's energy through a collector and using it to provide domestic hot water and space heating in the serviced building. Both diffuse and direct solar radiation are exploited by the system. Due to the seasonality of the solar resource and the majority of the space heating demand peaking in winter, such systems would greatly reduce the energy production and therefore fuel costs of existing conventional boiler systems in summer, but only partially do so in winter. Two main design types of the solar collector exist:

1. Glazed flat plate collectors – this is the most widespread and economic design in Europe. They are easily integrated on roofs and are characterised by insulation on their back and sides to minimise heat loss.

2. Evacuated tube collectors – they are more efficient than the previous, but also more expensive and cannot be integrated on roofs as they use glass tubes surrounded by a vacuum to minimise heat loss.

Solar thermal systems are usually coupled with some degree of existing or new water storage solution (cylinders or tanks) as peak heating in domestic buildings is necessary in the mornings and evenings while solar thermal energy production peaks in the middle of the day. As a result, retrofits based on this technology are more compatible with old dwellings serviced by conventional boiler systems already integrated with tanks and/or cylinders. On the other side, more recent properties are serviced by a combi boiler type, which provides almost instantaneously space heating or hot water on demand without the need of storage. Lastly, solar thermal systems can also be coupled with thermal absorption chillers in order to provide cooling during summer periods.

Solar thermal systems in the UK have a peak quoted thermal efficiency of around 70% (from estimation of nominal capacity over area). However, as a result of the UK solar resource seasonality and orientation of the collector, glazed flat plate collectors will collect around 350 kWh m^{-2} per year while evacuated tube collectors will collect around 450-550 kWh m^{-2} per year, which would correspond to annual plate efficiencies between 30 and 55%.

UK position:

Solar thermal systems are far less developed in the UK than solar PV installations, with only around 580 MWth total capacity in operation as of 2017. In this respect, the UK is behind other major European economies such as France and Italy, which have around 1,933MWth and 3,202MWth of installed capacity. There is also small progress in new installations, as only 8.5MWth were installed in 2017.

The UK does, however, benefit from a strong manufacturing base, with companies such as Kingspan, Viridian and AES quite active in the global solar thermal market.

UK costs:

Individual solar thermal installations are usually in the size range of less than 5-6 m^2, particularly when installed on the roofs of residential buildings. For smaller solar water heating systems (2-4 m^2), installation costs lie in the range GBP 1,000 – 1,500 per m^2; as the system size increases, installation costs can potentially drop down to GBP 800-900 per m^2. These estimations have to be treated as indicative because depending on the integration of the solar thermal panels with the existing heating system, additional costs can be incurred.

9.2.6 Emerging Technologies

This section briefly present some of the more novel solar technologies. These are still generally at the research and development stage, so are important to include to give an overall view of the solar sector but not significant in terms of actual projects in the ground for a solar roadmap.

9.2.6.1 Organic Photovoltaics

Organic photovoltaics (OPV) is another advanced technology which has the potential to reduce costs in manufacturing and materials by using a polymer blend. The highest efficiencies of OPV is currently at ~9%. This technology has some interesting novel applications with potential for OPV use in indoor lighting and in clothing.

UK position:

There has been significant investment in Eight19, based in Cambridge and Molecular Solar, based in Warwick. There is also research taking place at Leeds University and Imperial College.

9.2.6.2 Dye-sensitised solar cells

Dye-sensitised solar cells (DSC) is an advanced technology that uses a photoactive dye on a semiconductor support to adsorb light. DSC can be deposited on metal, glass and plastic which offers a potentially low-cost high-volume manufacturing route such as roll to roll coating. As this technology is still new its reliability has not been proven over time. The target market for this technology is mainly point consumers that do not require heavy electricity demands.

UK position:

There has been a recent advance at Oxford university that showed that using Perovskite as the absorber layer as a solid state approach.

9.2.6.3 Photovoltaic-Thermal Systems (PVT)

PVT systems combine photovoltaic and thermal solar energy conversion in a single collector, as the solar radiation not converted to electricity is then harvested to be converted to useful heat. PVT designs are mostly of the air collector type (the heat transfer fluid is air due to low capital cost), relatively few designs use a different approach with an uncovered water collector - despite this being the dominating PVT-technology. This indicates a lack of technological maturity despite multiple installations across the globe.

Overall, higher energy yields per area can then be achieved, as up to 70% of the incident solar resource is exploited. Nominal thermal power yields of 400 – 600 Wth/m^{-2} (40-60%) and nominal PV power yields of 100 - 200 (10-20%) are quoted by 26 PVT collector manufacturers surveyed by IEA SHC through a comprehensive international market survey (just one manufacturer is from the UK). The major obstacle represented by this technology is the increased upfront cost required. However, the overall levelised cost of energy of these systems can be 30-40% lower than that of equivalent PV-only systems. Current UK installation capacity is virtually non-existent (only 192 kWth and 62 kWpeak).

9.2.7 Cost summary for key solar technologies

An up-to-date average installation cost of the key solar PV project types specific to the UK market is provided in Table 9—2.

Table 9—2 Cost summary for different solar PV schemes.

PV setup	Small scale (0-4 kW)	Small scale (4-10 kW)	Small scale (10-50 kW)	Utility scale	Solar carports
Average installation cost (2019 GBP per kWp)	1816	1498	1139	1042	~1400

The small-scale project cost data have been gathered by BEIS from the Microgeneration Certification Scheme (MCS) database and mostly refer to roof-mounted, domestic systems installed in the period between January 2018 up and March 2019. Utility-scale projects are most often deployed in a ground-mounted arrangement; their average total installed costs have fallen an outstanding 77% since 2010 in the UK and benefit to a higher extent from economies of scale with respect to smaller scale installations. Finally, UK solar carports are still a novel concept and costs more than conventional commercial installations, as a result of the increased complexity of integrating the solar modules with the canopy roofs. However, they are also able to unlock more niche revenue streams given their strategic location and future integration potential with EVs in public parking spaces.

9.3 Context for solar development

This section outlines the financial support mechanisms in place for solar generation. It also gives a brief summary of planning considerations and the current status of solar in the area.

9.3.1 Economic support frameworks

The UK's solar legislation has changed considerably over time, most recently there was a Feed in Tariff (FIT) scheme, however, this was closed to new entrants on 31st of March 2019. The closure followed consultations in 2015 and 2018, to reduce the costs to consumers as the price of installing solar panels came down, the cost of residential solar installations has come down by 50% since 2011 according to the UK government. A review of the UK legislative framework applicable to solar energy is provided below, this is focused on subsidised generation of solar power.

The **Renewable Obligation (RO)** was one of the main support mechanisms for large-scale renewable electricity projects in the UK. The RO came into effect in 2002 in England, Wales and Scotland and 2005 in Northern Ireland. It places an obligation on UK electricity suppliers to source an increased proportion of their electricity from renewable sources. Renewable Obligation Certificates (ROCs) were issued to accredited renewable operators and the certificates were used by suppliers to demonstrate that they had met their obligation. The scheme closed in March 2017, to be replaced by Contracts for Difference (which are discussed later).

Contracts for Difference (CfD) has replaced the RO as the UK government's main mechanism for supporting low-carbon electricity generation. This is done by incentivising renewable electricity by providing developers with high upfront costs and long lifetimes with direct protection from volatile wholesale prices through an agreed strike price. This also protect consumers from paying increased support costs when the price of electricity is high.

Renewable generators can apply for a CfD and there can be a range of renewable technologies competing directly against each other for a contract, in auction process. Successful developers of renewable projects enter into a private law contract with the Low Carbon Contracts Company (LCCC). With the developers being paid a flat rate for the electricity they produce over a 15 year period, agreed during the auction process.

Solar projects are not generally supported through this scheme – with none appearing in the latest round of funding. The majority of the CfD auction went to offshore wind projects, at ~40£/MWh. This makes a useful comparison point for solar power in the UK if it is going to compete with large scale renewable grid decarbonisation.

The UK **Feed-In Tariff (FIT)** was designed to engage small scale renewable electricity production, such as at the household level. This gave payments (generally quarterly) for the electricity generated and exported to the grid. The focus of this was on small scale projects, below 5MW, with projects of a smaller size achieving a higher price per unit of electricity. Payments are made based on the meter reading that generators submit to their electricity supplier. The scheme was introduced in April 2010 and led to a massive increase in uptake in solar PV in the UK, ~840,000 solar installations since the start of the scheme, this is explored further in a Greater Brighton context in Section 4.

The FIT support has now been removed in the UK (ending 1st April 2019) which along with the competitive nature of the CfD means in the UK solar power is generally having to compete with other forms of generation without market support, although it is being replaced to an extent by the smart export guarantee, discussed below.

The FIT has to an extent served its duel purposes of increasing solar installations and bring down costs. Whilst the costs have come down (estimated total install cost including equipment in a domestic environment to have dropped from ~5000£/kW in 2010 to ~1700£/kW at the start of 2019), with no FIT market commentators consider a 17 year payback is the best that can be expected through export [1].

The **Climate-Change Levy (CCL)** is an environmental tax charged on the energy used by businesses and has been designed to encourage businesses to be more energy efficient in order to reduce greenhouse gas emissions. The tax was first introduced in April 2001 and was forecast to cut annual emissions by 2.5 million tonnes by 2010. The CCL applies to businesses in the industrial, public services, commercial and agricultural sectors. Originally the electricity generated from renewables and approved cogeneration schemes was not taxed but this exemption was removed in the July 2015 budget.

The **Renewable Heat Incentive (RHI)** is a government financial scheme to promote the use of renewable heat and contribute towards the 2020 ambition of 12% of heating coming from renewable sources. BEIS develops the scheme policy and rules and Ofgem implements and administers the scheme. From a solar perspective the significant element is a 21.09p/kWh currently being given for solar thermal projects. Meaning in terms of subsidy solar thermal technology is the only technology currently strongly supported by the UK government, in a generation context.

The UK Government are replacing the FIT scheme **Smart Export Guarantee (SEG)**, new laws guarantee payment for small-scale generation that provides excess electricity to the grid – as with the FiT small scale generation is considered to be <5MW. Part of the scheme is that it will not be paid for by fees added to consumer bills, aligning with a central Government aim that renewables, although seemingly not nuclear, will part of a UK transition to a 'subsidy-free, cleaner and greener energy system'. The inclusion of a support mechanism for small scale renewables is promising for solar. The SEG only recently finished its consultation period so the exact extent of the support is yet to be made clear. The efficiency of the scheme is going to be aided by tracking the generation using smart meters. The combination of distributed generation, smart meters and battery storage, SEG is aimed to help bridge the gap to a smarter and more efficient energy system. For this to be successful SEG users will need to be able to participate more actively in the electricity, taking advantage of different tariff structures.

Whilst the SEG shows some promising for solar power the UK Green Finance Strategy, an 80-page document launched in July 2019, makes little mention of solar PV. Nuclear power and offshore wind both focus areas, whilst solar PV is only discussed in passing and as a sector to be tackled in other countries. Thus in the most part solar has limited support in the UK.

9.3.2 Planning

Historically planning permission has been relatively easy to obtain planning permission for both roof and ground mounted systems. For roof mounted systems solar panels are generally a permitted development right – which means they do not need to acquire planning permission. However, there are still guidelines to be met. Permitted development rights are more restricted on listed buildings and in Conservation Areas, National Parks and Areas of Outstanding Natural Beauty – which impacts large areas of Greater Brighton. Whilst these are unlikely to limit rooftop PV listed buildings are more likely to be a barrier for some developments but should not significantly impact the area's rooftop PV potential.

Ground mounted solar systems face larger hurdles. The South Downs National Park authority states that installations must comply with other relevant policies will be encouraged providing that:

- The siting, scale, design and appearance will not have an adverse impact upon landscape character, including cultural heritage, and wildlife;
- adjoining uses, residential amenity and relative tranquillity are not adversely impacted in terms of noise and disturbance, vibration, stroboscopic effect, or electromagnetic interference;
- existing public access is not impeded;
- and the installation does not result in the loss in use of Grade 1 or 2 agricultural land.

The final point is true for all areas in terms of agricultural land, with Grade 3 also requiring further justification than Grades 4 and 5 (which are preferable). A useful summary of planning legislation for solar power is provided by the BRE [2], however Figure 3 Figure 9—3provides a rough summary of areas which should be excluded from ground mounted PV due to land use. In terms of landuse this is taken to be any area which is Grades 1-2 agricultural land urban areas, non-agricultural areas and wooded/forested locations should also be considered constraint areas and Grade 3 suboptimal.

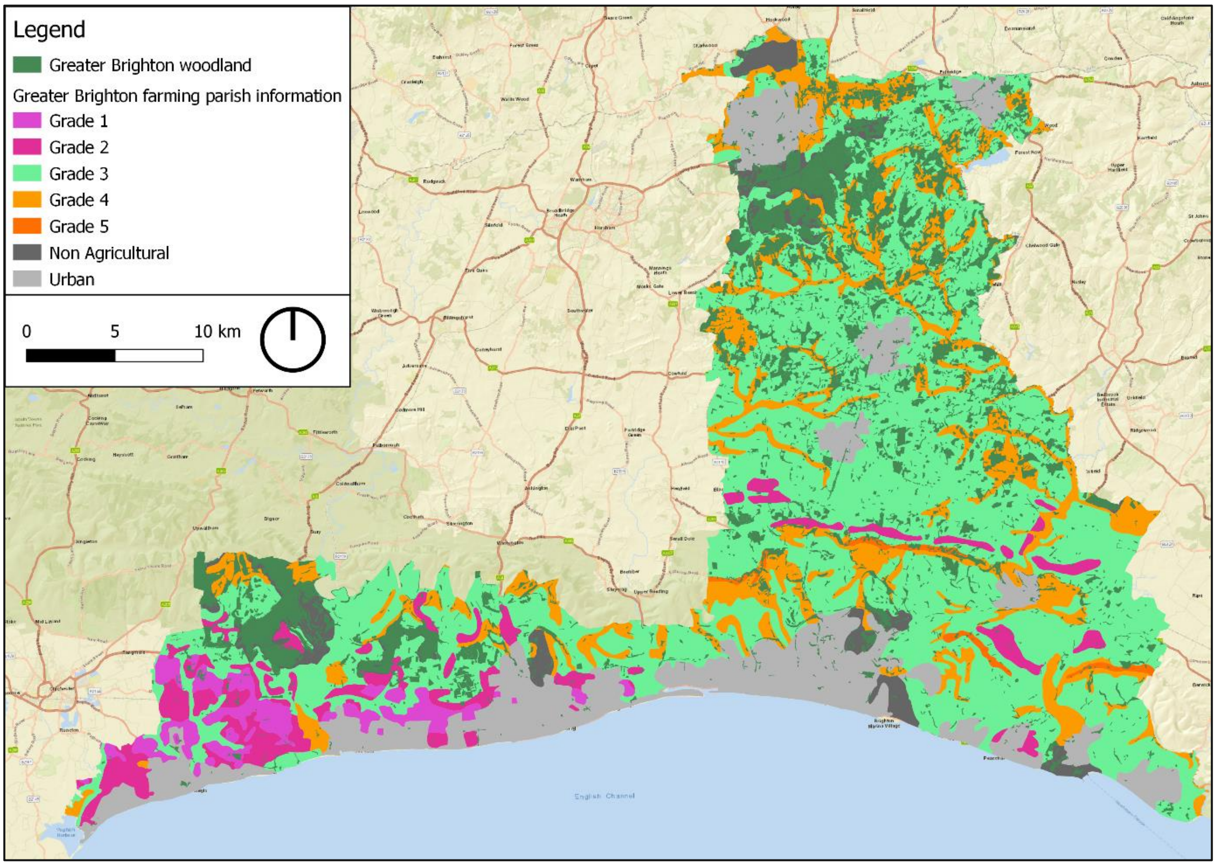

Figure 9—3 Summary of land classification constraints areas for solar farms in the Greater Brighton area. The map is compiled using the UK Government agricultural land classification data and forestry commission woodland data.

There are several large areas of constraint for large scale ground mounted solar generation, the most notable being the extensive urban conurbation along the coastal region. Figure 9—3also shows that low grade agricultural land (Grades 3-4) makes up a relatively small portion of the land take, with Grade 3 dominating. However, if large scale ground mounted solar was deemed desirable this allows rapid identification of priority areas. It should be noted that due to the visual impact large tens of megawatts scale projects are unlikely to be tenable in the national park area of Greater Brighton, regardless of land use.

9.3.3 Current status of solar in Greater Brighton

Combining two UK Government datasets (feed-in tariff data and UK renewable power plant data) a total of 177MW of solar capacity has been identified in the region, this makes up ~1.3% of the UK total. However, behind the meter and schemes may not be captured and some of the more recent developments may not be captured at a local level. Despite this the relatively small percentage share given that the area represents one of the best solar resource areas in the UK (see Figure 9—4). This is likely in part due to the high land value and constraints illustrated in Figure 9—3.

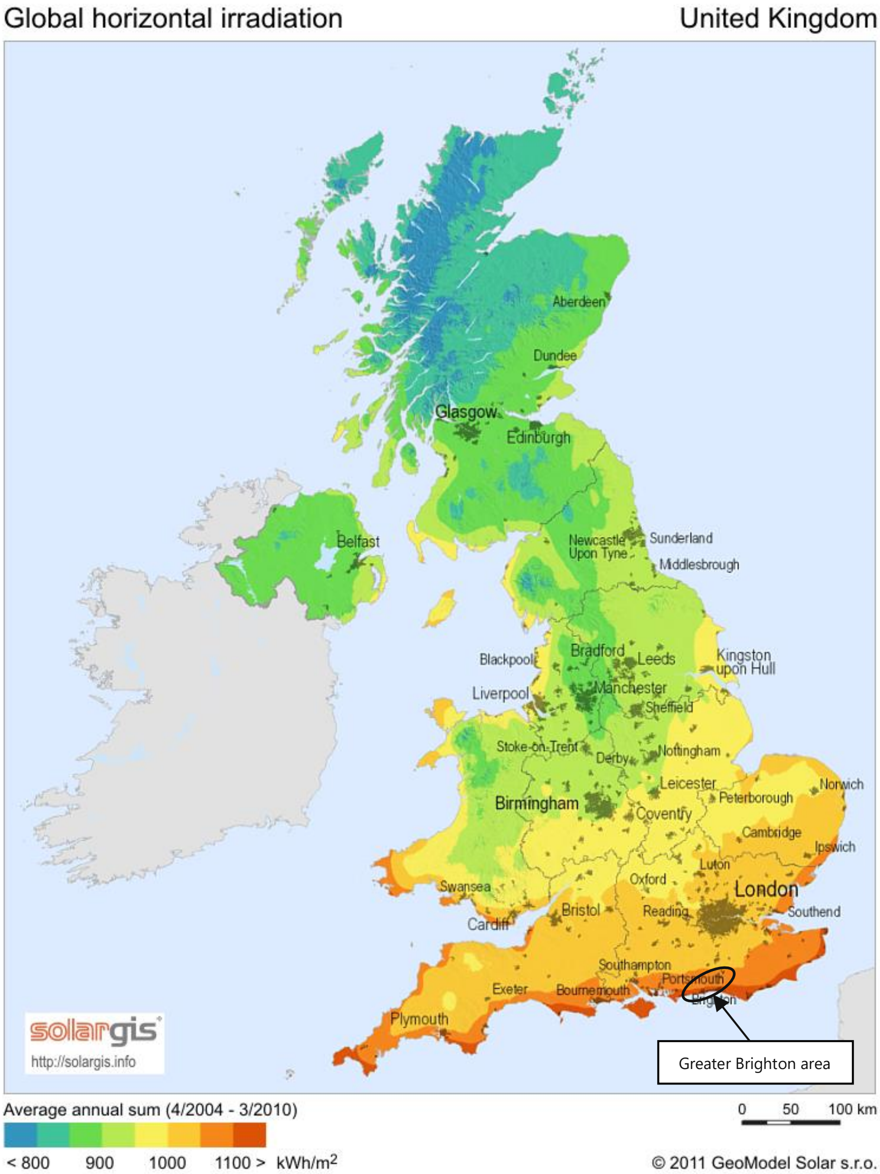

Figure 9—4 UK solar resource with approximate location of the Greater Brighton marked. Background image from Solar GIS.

A detailed geographic breakdown of solar capacity in Greater Brighton is provided below in Figure 9—5; this includes both larger PV farms (with data drawn from a BEIS data set giving precise coordinates of solar farms) and the FiT presenting data presenting installed small scale connections. The FiT data is presented at Lower Layer Super Output Area (LSOA) level, LSOAs are distinct geographic areas used for breaking down census statistics covering about 1500 people.

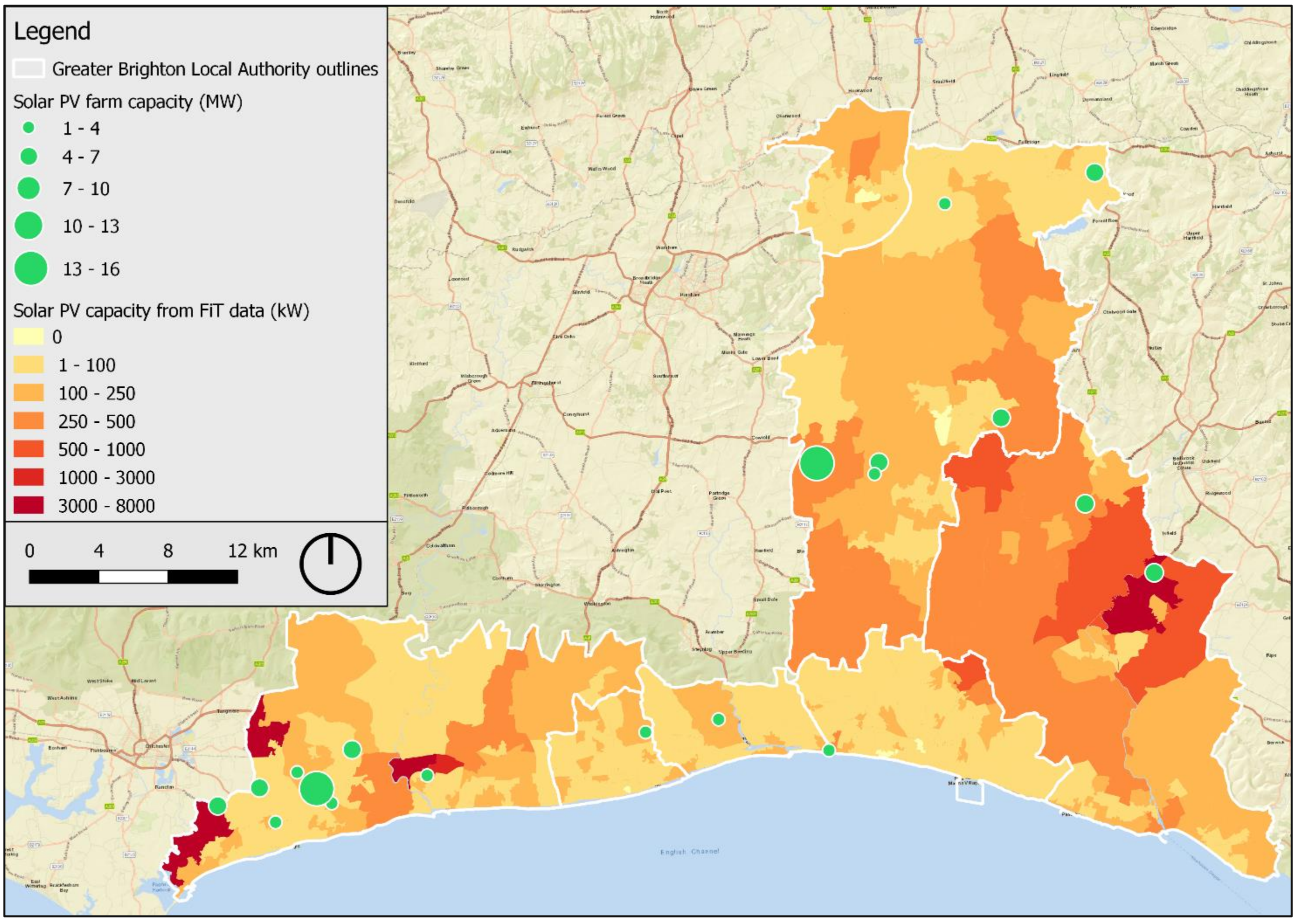

Figure 9—5 Current solar installations in Greater Brighton.

The distribution of large scale solar generation matches well with the constraints map, it also highlights that Arun is leading the way in solar development in the Greater Brighton area for these types of developments with Mid Sussex being the next highest in terms of capacity. In terms of small scale FiT capacity Arun again performs well in terms of installed capacity per LSOA along with Lewes. It should be noted Figure 9—5 does not include the boundaries of the LSOAs, so if adjoining LSOAs fall into the same capacity banding they will merge (this is due to in urban areas LSOAs being spatial small - so differentiating would hinder interpretation). The FiT capacity breakdown for the different LAs is:

- Adur 2,694kW
- Arun 23,399kW
- Brighton and Hove 8,004kW
- Crawley 4,484kW
- Lewes 13,012kW

- Mid Sussex 8,520kW
- Worthing 3,395kW

The FiT data for Greater Brighton is illustrated with temporal detail in Figure 9—6, it should be noted in 2012 and 2016 there were particularly large cuts to the FiT.

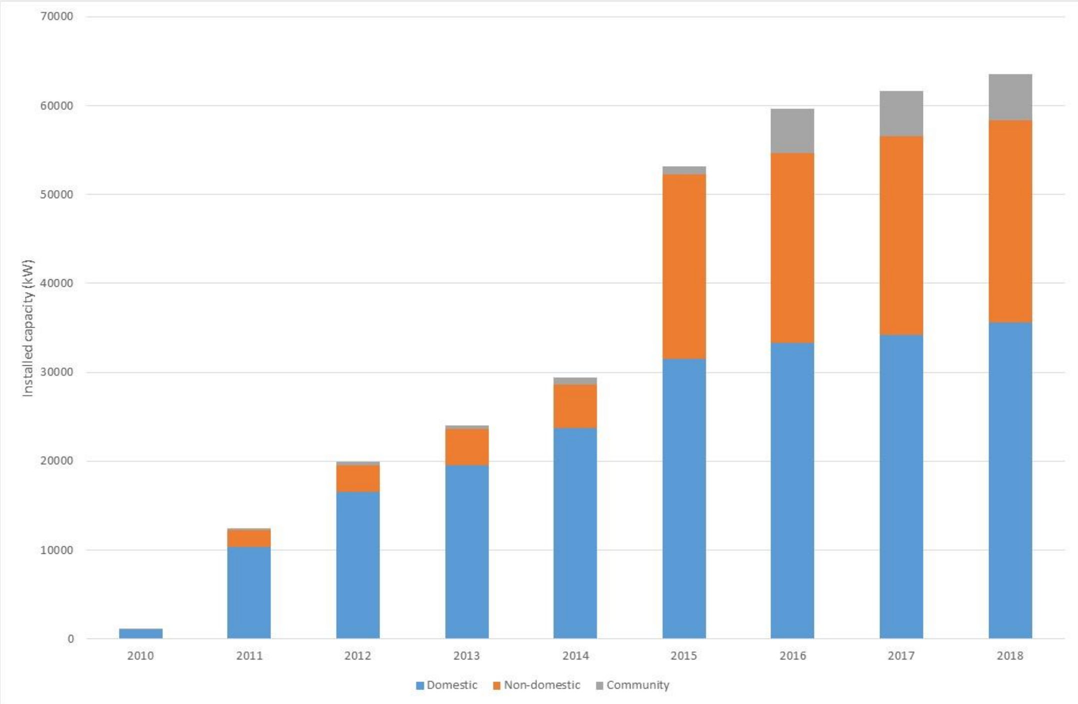

Figure 9—6 FiT registered solar projects in Greater Brighton, split by project type.

The growth in solar capacity is markedly faster between 2010 and 2012 than 2012 and 2014. This is due to the first review in FiT rates happening in 2012 and resulting in fewer people investing in PV. The market then recovered with percentage growth in uptake of the FiT peaking in 2015, however, once the impact of the rate cut (65% in 2016) filtered through the market stagnated - with a dramatic decrease in percentage growth in 2016 and beyond.

This market uncertainty had large impacts on the solar industry and supply chain. A notable example in Greater Brighton being the loss of the company Southern Solar in 2015, which had been operating since 2002, and been heavily involved in promoting the growth of community owned solar projects in the Greater Brighton area.

Community owned projects and community energy companies are a key theme that came out of the stakeholder engagement part of the project and is an area that Greater Brighton continues to be a leader in at a national and global level. These will be explored further in the projects and delivery models sections.

9.4 Solar projects in Greater Brighton

As shown in Figure 9—6 the solar market has generally stagnated in the area, due to the cuts in FiT. However, one sector which has managed to buck this trend is the community generations sector (this is slightly hidden in the data for Figure 9—6, possibly due to the presence of PPAs for the electricity produced). This is in part due to an extension of the FiT for community projects of one year, which resulted in a very high level of interest in 2019.

9.4.1 Solar schools

A model frequently used by community energy groups in the area is that of solar schools, where the community energy group will gather shareholders to invest in the scheme, construct solar PV on the roof space and sell generated electricity to the school through a PPA at a lower price than it could purchaser electricity through a standard supplier. Brighton Energy Cooperative, OVESCO and BHESCo are all active community groups in Greater Brighton promoting solar schools. Well over £2million of funding has been raised by these groups for solar school projects. As solar schools have a business model which is proven (discussion with community energy groups suggests this is the case even without the FiT – although it does mean payback rates have fallen) it seems an excellent opportunity for a solution to be rolled out across the region. A regional energy investment company would be an excellent vehicle to achieve this, allowing for an increase in scale and deployment rate. If the energy investment company was to be Greater Brighton based it would likely be happy to accept a slightly lower rate of return than private companies, ensuring rapid project uptake. The scale of deployment could be significant, with the area containing several hundred schools and projects generally ranging from a few tens of kW for primary schools to several hundred for large secondary schools and colleges. Assuming an average install of 60kW across 250 schools this would equate to 15MW of capacity but the potential could be more than double this.

Community energy groups in the areas should be heavily engaged with activity in this area due to their experience and expertise and engagement with the supply chain. It should be noted that there are signs the supply chain is not currently geared towards rapid deployment of applications like this; the extension of the FiT for community projects meant that so many projects were put forward in some areas that they could not be deployed in the required timescale (although there are none in Brighton and Hove which seem to have suffered from this issue).

9.4.2 Solar landfill sites

In the Tri-LEP study the utilisation of old land fill sites for solar power is flagged as a key opportunity for large scale solar deployment. In the initial instance this is because the sites generally have little productive value and require many years of remediation before they are suitable for regular development. Large sites are also frequently owned by the LA and thus are an area where the Greater Brighton Authority will be able to focus.

The tri-LEP study also flags that many landfill sites are already linked to the electricity grid – in order to feed in electricity generated from gas turbines run on the methane produced on site. As the gas diminishes additional capacity could be freed for solar generation and the gas could be managed to not generate during daylight (this would also help maximise value from the gas). However, as not all landfill have gas turbines since this will not always be suitable.

Historic and active land fill sites were examined and validated initially in GIS, rejecting some due to constraints (such as use as playing fields or very high visual impact due to location in the National Park) and a size of 40,000m^2 to ensure high level installed capacity (4MW and over) – to optimise economics. This left 20 landfill sites that were considered suitable for consideration for solar PV in the region (seven of which are still active).

9.4.3 Solar car parks

Solar car parks utilise solar power to feed into electric vehicle charging points. The PV itself can be land based next to the car park, rooftop based or utilising purpose built canopies. Brighton Energy Cooperative are currently examining solar carparks and Brighton & Hove carried out an exercise to identify suitable locations (analysis of this latter data only flagged one site – on Rottingdean seafront). Big Lemon buses can probably be considered the pioneer of this technology application the Greater Brighton with solar panels on their depot site being used to charge electric buses (it was the first with this kind of application in the UK).

Solar car parks are considered to have extra value beyond feeding directly into the grid, from a Greater Brighton carbon perspective as they help to directly displace transport emissions.

A developed case study for PV car parks is provided in Section 8.5 for a multi-storey car park in Haywards Heath. This site is next to a train station which we identify as an important focus for such charging hubs due to the length of stay and the wider mobility model work this meshes into – which will be required for successful decarbonisation of transport.

9.4.4 Solar thermal

Currently solar thermal is considered for rooftop installs, for utilisation within the same building. To reach full decarbonisation of the energy system heat presents a greater challenge than electricity, so in some instances solar thermal on a roof may be of more value than PV. However, the technology is not as widely considered by the public. To address this local schemes above the central UK Government RHI seem to be required to increase uptake. Additionally, LA owned assets would be useful place to start increasing installs – providing a guaranteed base to help grow the supply as well increase public familiarity with the technology.

BEIS are potentially looking to develop a work stream examining solar thermal heat networks. If these are shown to be practicable there may be several opportunities within the Greater Brighton region which would suit this approach. Opportunities should be monitored and if funding is available try to promote a pilot scheme in the region. Which would be well suited to this technology application due to the high solar resource (for the UK) and areas with large population densities. Thus it is suggested opportunities in this area are monitored.

9.4.5 Large scale rural community solar

The Greater Brighton region is one of the leaders in large scale renewable community solar projects. An exemplar project model is that of Riding Sunbeams – where direct supply of solar power to rail traction systems. Projects will be funded by offering shares to communities and commuters, allowing local people to own and benefit from the low carbon electricity powering their trains. Being community projects they are able to leverage additional funding through the Rural Community Energy Fund, with multiple communities biding in a combined manner to pool funding. This is necessary given the scale of the projects, with one Riding Sunbeams proposed site in the Greater Brighton area being 11MW. A full project breakdown is provided in Section 8.6.

Rural communities are suited to large scale solar projects due to substantial land assets, however, they are often on the extremity of the grid making connection difficult. In a pre-development project identified in the questionnaires a 4.2MW combined solar and battery installation was identified in the rural community of Firle. Having a battery integrated into the development helps reduce the impact of grid constraints in the area as the power can be more easily utilised and managed within the local area, helping to reduce pressure on the grid.

At Barcombe (another rural village) there is also discussion of a community solar farm, with the proposed funding mechanism for this including a community bond. Barcombe is currently pursuing major funding form the Network Innovation Competition, to help determine how issues such as grid constraint for decarbonisation can be overcome through innovative approaches. More details of the scheme can be found in Section 8.3.

If novel solutions can be found to grid constraint issues there is seen to be significant potential for community solar farms in the rural areas of Greater Brighton. The National Park Authority seeming to present relatively little deviation from national policy in terms of suitability of sites for deployment. As shown in Figure 9—3 there are large tracts of suitable land, particularly grade 3 agricultural areas. As grade 3 is not preferred but not a hard constraint having a community ownership aspect is seen as a positive factor for deployment in these areas. It should be noted there is likely to be a limit to the level of solar which will be considered acceptable, due to the cumulative impact of multiple installations to the area's character. Consequently, particularly in the National Park there will be a limit to the number of solar farms that will be considered acceptable.

9.4.6 Encouraging large scale solar deployment for high energy users

It is suggested that the largest emitters are the best to initially target for solar power to displace onsite carbon emissions, these are illustrated in Figure 9—7.

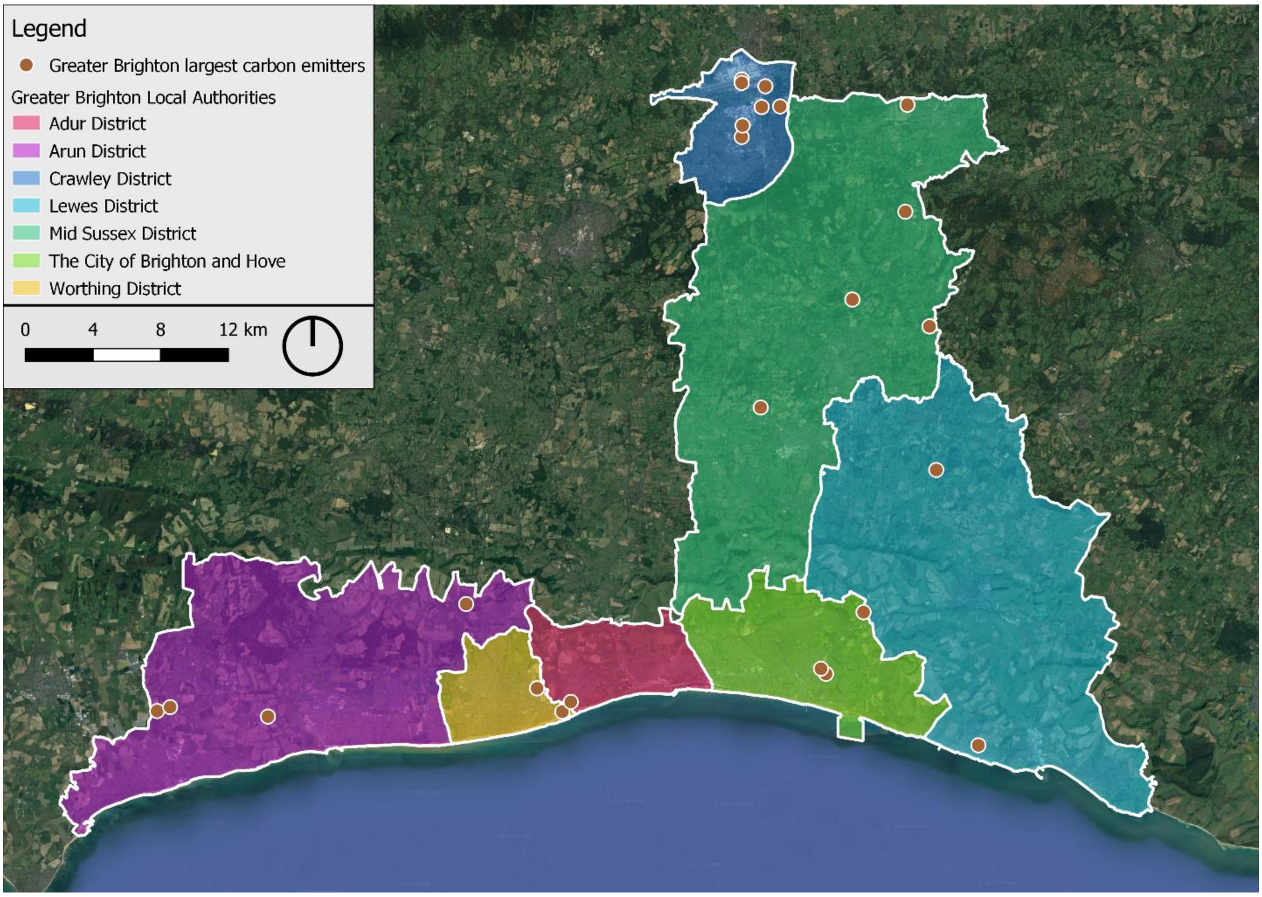

Figure 9—7 Largest single carbon emitters in the Greater Brighton area[7].

The map highlights the density of high emitters in Crawley, Gatwick Airport and the Manor Royal business park are responsible for most of these. Gatwick has its own advanced energy strategy and Manor Royal is progressing with measures to enable large scale PV uptake. At Manor Royal this is being assisted through the BISEPS scheme (funded through INTERREG), where multiple applications of solar technology are being explored.

[7] Emissions data taken from the NAEI (https://naei.beis.gov.uk/emissionsapp/), data was filtered to exclude power plants which should be considered separately (notably the energy from waste facility at Newhaven and Shoreham Power Plant).

The universities in Greater Brighton are also flagged in the carbon analysis as large emitters in the GIS analysis. Both the University of Sussex and the University of Brighton are using solar to address this issue, with Sussex University's rooftop solar project in 2017 being the largest install at a University in the UK at the time.

Shoreham Port is another large emitter in the area and is pioneering the way to reduce emissions through multi-vector and technology applications. This includes large scale rooftop deployment of solar panels, a technology to which the building typology of industrial sites like this is well suited (e.g. warehouse rooftops).

The water provider in the area, Southern Water, is highlighted as one of the largest single emitters in the Greater Brighton region. Southern Water provided details of all sites that are being considered for solar generation, with only two sites appearing in the Greater Brighton area (Arun was a late inclusion in the project area and was not included in this part of the analysis). However, there were many areas considered outside the Greater Brighton area, showing that is an issue with suitable assets rather than lack of commitment to solar power.

Floating solar PV on water reservoirs is becoming an increasingly established technology a GIS scan of the region was carried out to try and locate any suitable sites – however none were identified. The largest reservoir is at Ardingly in Mid Sussex but this is heavily used for activities, including sailing, and so considered unsuitable for development.

9.5 SWOT analysis of solar projects

A succinct SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis now follows, split into the different typologies of projects identified: domestic rooftop PV, non-domestic rooftop PV, solar farms, solar thermal and solar carports. The relative solar resource abundance in the Greater Brighton area with respect to the rest of the UK represents a significant strength for all types of solar installations analysed next.

9.5.1 Domestic rooftop PV

Domestic rooftop PV installations are largely constrained by the roof space availability of residential buildings. Average peak capacities are around 2.5 – 4 kW, occupying roof areas of 20-30 m^2. The proliferation of these systems in the early 2010s was mainly a result of the introduction of generous FITs in the domestic sector.

Key to this is removal of feed-in tariff and slow down of install

STRENGTHS	WEAKNESSES
• A familiar solution which is now an every day sight • The discontinuation of domestic FITs is to be followed by the introduction of the SEG in January 2020, demonstrating the commitment of the government to support the specific domestic PV market. • The SEG will promote competition between energy suppliers with 150,000 or more customers to offer an appropriate export tariff to remunerate domestic PV owners. • Initial SEG tariffs are expected to be relatively close to the export tariff in the final quarter of the FITs scheme (Energy Saving Trust). • When coupled with heat pump solutions they can provide very efficient low carbon heat (due to COP of heat pump technology).	• PV installations in the UK residential sector have fallen dramatically from a peak rate of 55,000 installed units per month in 2011 to just 2,000 – 3,000 per month in early 2017 due to reductions of government subsidies in the sector. • The government has gradually reduced tariffs of domestic FITs (in particular the generation rate), in conjunction with capital cost reductions of installations, eventually closing the scheme in March 2019 and creating uncertainty in the market. • SEGs do not have a set or minimum export rate (just that it shall be greater than zero). • Coupling solar PV with domestic batteries is currently expensive and even more costly if residents wish to use the system for resilience • Still very low uptake despite having had incentives, demonstrating lack of buy in for adoption • Lack of incentive for private landlords to fit on to rental properties

	• Payback can currently be many years which is not attractive unless residents plan to stay for the period • Typical installations are very susceptible to shadowing which limits scope and yield •
OPPORTUNITIES	**THREATS**
• Great integration opportunity with domestic ASHPs and GSHPs and EV charging providing for loads during the middle hours of the day can greatly reduce peak evening loads (continuous heating mode over two times a day mode). • Lower export PV tariffs than import grid electricity tariffs promote self-consumption (up to 45%) and more conscious energy usage (https://doi.org/10.1016/j.enpol.2018.04.006). • Directly supports a (visual) strategy for decarbonisation in the region, raising awareness. • With the right financial support mechanisms can help to mitigate fuel poverty by reducing bills • •	• Supply chain could reduce significantly following FiT unless market uptake is maintained • Electricity network capacity could provide a barrier to update due to local constraints if not managed properly • Participation to the SEG is dependent on the presence of a smart meter, which only has a 30% penetration rate in domestic metered households and even lower for domestic PV arrays (BEIS "Smart Meter statistics in Great Britain: quarterly report to end June 2019).

9.5.2 Non-domestic rooftop PV

Non-domestic rooftop PV installations tend to be greater in size with respect to non-domestic installations and characterise both commercial and public sector buildings, such as car parks and schools.

To include projects such as co-location with EV charging/car parks and solar schools

STRENGTHS	WEAKNESSES
• No planning complications for public sector buildings. • Public sector rooftop PV installations can become "quick wins" for attracting private renewable energy investment and further public funding. • Rooftop PV farms on schools promotes social responsibility in classes. • Proven engagement and crowd funding success in the region. • Direct route and quick installation to support decarbonisation strategy • Large roofs can give good yield to support local power consumption	• Reduced power load requirements of commercial and public sector buildings in weekends and holidays that therefore do not match PV profiles. • Odd roof arrangements and physical obstacles of non-domestic rooftops might limit PV installation capacities.
OPPORTUNITIES	**THREATS**
• Large untapped energy potential represented by car parks (with integrated EV charging and batteries) and school roofs. • Can create alternative revenue streams for LA to promote inclusive growth or further energy investment. • Can promote the take-up of EVs with car parks PV installations. • Opportunity to develop local expertise and engineering resources.	• Might require specific expertise in the local authority resources or partnering with more capable private companies. • Relatively long payback periods might put off private investment contributions. • Supply chain could reduce significantly following FiT unless market uptake is maintained

• Demonstrable visual driver to show decarbonisation is being taken seriously • Can be used to provide cheap energy to consumers through PPA arrangements	

9.5.3 Solar farms

Solar farms primarily comprise large-scale, ground mounted installations, usually connected to the grid for the sale of PV electricity in the wholesale market or through private PPAs. As a result, they require large extensions of lands.

Primarily large scale ground mounted solar, e.g. Riding Sunbeams and solar landfill sites

STRENGTHS	WEAKNESSES
• Solar farm businesses are sometimes owned by community schemes, benefitting the local community and promoting inclusive growth. • Solar farms are relatively large-scale and therefore their significantly large energy output can be traded through PPAs, minimising the investment risk. • Solar farms can benefit from economies of scale and represent more viable business cases. • Recent technological advances in solar PV designs can overcome stability issues of uneven land. • Established models for deployment • Can often be deployed on low value land	• The feasibility of solar farm installations is limited by the available distribution network capacity. • There is currently no incentive from the central government for DNOs to increase connection capacity/ points. (https://doi.org/10.1016/j.renene.2018.08.109.) • Visual impact may be of concern to nearby residents • Lack of subsides means revenue schemes need to be carefully considered
OPPORTUNITIES	**THREATS**
• Possibility to exploit a large number of former landfill sites with no other productivity potential, unfit for other economic activities and characterised by existing grid connections. • High concentration of Network Rail load hotspots (traction and non-traction electricity demand) that can be directly connected to the solar farms, bypassing the grid. • Significant job creation potential. • PPA agreements with large consumers can reduce energy costs and decarbonise whilst providing long term revenue • Revenue stacking potential to support business case • Coupled with storage can provide multiple energy services and mitigate network reinforcement	• Risk of congesting the local distribution network if solar farms are connected to the grid and not to significantly large load hotspots. • Natural obstacles can pose major structural risks to solar farm installations and cause project delays and costs increases. • Public resistance due to visual impact • Short term revenue contracts for flexibility services may diminish •

9.5.4 Solar thermal

Solar thermal in the UK has lagged behind PV since the FiT was introduced but as the focus shifts to decarbonisation of heat it is seen to potentially have an important role to play.

STRENGTHS	WEAKNESSES
• Heat decarbonisation solution which would not put additional stress to the grid network and does not depend on the presence of infrastructure.	• Solar thermal collectors performance is greatly dependent on the outside ambient temperature, the heat transfer fluid inlet temperature and the minimisation of heat loss to the environment, requiring specific design work and control strategies (https://doi.org/10.1016/j.solener.2018.01.013).

• Can establish great synergies with domestic and commercial heating systems with existing water storage (more likely to be older boiler systems) and with district heating projects. • Can be combined on the same collector with solar PV technology to harness the wasted solar resource, although at an additional capital cost. • Useful solar thermal energy densities are higher than useful solar PV energy densities (350-600 kWhth m^{-2} vs. 230 – 140 kWhe m^{-2} in Greater Brighton) • Benefits from the most generous domestic RHI tariff (extended until 2021), helping to reduce payback periods. • Market model is simple, consumer saves energy. Not associated with multiple metering or tariffs.	• Most common thermal collector designs are of the glazed flat type, the most inefficient type. • Requires a hot water tank • Not a familiar technology to many in the UK • Payback is often over very long period of many years • No market incentive to bulk deliver due to lack of revenue streams e,g, through PPA or roof rent.
OPPORTUNITIES	**THREATS**
• Great integration potential with cooling technologies (absorption chillers) particularly in commercial applications. • Heat decarbonisation can be achieved without increasing peak electrical demand, which could be the case with electrification solutions. • Opportunity for proving its decarbonisation potential, given that it is much less visible than solar PVs in the UK. • Make people aware of RHI •	• Less established supply chain and in particular installer base than solar PV. • More complicated installed system and more capital intensive projects with respect to solar PVs might put off investors and project owners. • Unclear subsidy system after RHI

9.5.5 Solar carports

Solar carports are a relatively new business model disrupting the UK solar PV market only in 2015, with the first two 150 kW installations built on top of multi-story car parks in Exeter. The system integrates a PV-equipped roof with traditional parking canopies, with additional battery storage in some instances. Given the strategic location of these structures in public parking locations, projects have started including the procurement of a number of EV charge points in the parking spaces, supporting the transition of the mobility industry to electrification.

STRENGTHS	WEAKNESSES
• Synergistic integration of established (solar PV) and emerging (battery storage and EV charging) technologies. • Supports EV uptake in the area. • Additional revenue potential for project owners (whether private or public) • Modular designs of this product already available. • Visual appeal and enhanced service offering of the carpark. • Ideal PV arrangement in sites where roof space is restricted. • Can offer lower cost energy to consumers	• Lower ROI than other PV project types? • Relatively low commercial maturity of battery storage, particularly in the EV context. • Requires new commercial models and digital platforms to retail • Current EV uptake may not support investment
OPPORTUNITIES	**THREATS**
• Opportunity to reinforce a relatively unknown business model (tested already in the UK) and make it more visible. • Possibility to provide building and mobility carbon reduction savings simultaneously.	• Threat of unjustified investment for commercial estates with respect to other estate refurbishments?? • Low maturity level of current EV market. • Benefits might not be reaped immediately as a result of the slow EV uptake.

• EV grid frequency response demonstration opportunity. • Could accelerate EV uptake if done as part of a mobilisation strategy	• Technical challenge of specific PV application. • Mobility models may change in the future leaving stranded assets

9.6 Priorities and Recommendations for increasing uptake

Combined purchasing power of Local Authorities is seen as key to bring down cost for solar power and replace some of the shortfall seen due to the removal of the FiT. A Greater Brighton Energy Investment Bank is seen as another key mechanism, this could take forward projects which are economically viable but would not stand up to the rates of return required by traditional private investment. Multiple projects which are directly replicable would be suited to an Energy Investment Company approach, such as solar schools and PV car parks. In the case of the former this is seen as an immediate priority, which through Local Authorities and One Public Estate Greater Brighton is well placed to accelerate. Even without an Energy Investment Company these bodies could help bring projects to community energy groups (by creating a day event for head teachers and school governors, for example). The trust, expertise and existing supply chain links of community energy groups are seen as key, certainly in the near-term, for enabling increased solar development in Greater Brighton.

Projects identified across the Greater Brighton region indicate in the order of 300 MW of additional installed PV capacity is seen as tenable. This should focus on onsite utilisation and will be of particular use, from a carbon perspective, when coupled with heat and transport technologies.

10 Carbon modelling

A model was built to undertake analysis of the impacts of projects and decisions on decarbonising Greater Brighton's energy system. These included specifically identified heat networks, an additional ~300 MW of solar generation in the Greater Brighton area, a transition to low carbon transport (a mix of hybrid vehicles, EVs, and hydrogen busses and HGVs), energy efficiency, and heat pumps (the majority of which are hybrid to maintain the flexibility of gas in the system). Some of the assumption for heat are hard to draw out from the results and are summarised in Table 10—1 Key percentage based assumptions for heat in the Greater Brighton energy plan.Table 10—1.

Table 10—1 Key percentage based assumptions for heat in the Greater Brighton energy plan.

	Heat demand reduction	Electricity demand reduction	HEAT SCOP	Space heating SCOP	Cooling SEER	Cooling delivery efficiency	On-site Generation	Fuel
Domestic Retro-fit (fabric)	17%	10%	0%	0%	0%	0%	0%	n/a
Non-Domestic Retro-fit (fabric)	20%	30%	0%	0%	0%	0%	0%	n/a
Smart meter installation	10%	10%	0%	0%	0%	0%	0%	n/a
Solar Thermal	50%	0%	50%	50%	0%	0%	100%	n/a
Behaviour change (domestic)	5%	5%	0%	0%	0%	0%	0%	n/a
Behaviour change (non-domestic)	5%	5%	0%	0%	0%	0%	0%	n/a
Heat pumps (domestic)	0%	0%	250%	250%	450%	116%	0%	Electricity
Heat pumps (non-domestic)	0%	0%	350%	350%	450%	116%	0%	Electricity
Hybrid Heat pumps (domestic)	0%	0%	250%	250%	0%	0%	0%	Electricity
Hybrid Heat pumps (Gas)	0%	0%	91%	91%	0%	0%	0%	Gas
Heat network connection	0%	0%	100%	100%	0%		0%	District heat
New Direct Electric heating	0%	0%	95%	95%	0%	80%	0%	Electricity
Hydrogen boiler	0%	0%	80%	80%	0%	0%	0%	Gas
New Gas boilers	0%	0%	91%	91%	0%	0%	0%	Gas
Existing gas boiler	0%	0%	85%	85%	0%	0%	0%	Gas
Existing Oil heating	0%	0%	70%	70%	0%	0%	0%	Oil
Existing Direct Electric heating	0%	0%	90%	90%	0%	80%	0%	Electricity

10.1 Carbon emissions

A baseline was established for carbon emissions using historic government data and then forecast taking into account information such as population growth and the impact of national and local policies and projects identified through the Energy Plan. The results of this are summarised in Figure 10—1.

Figure 10—1 Summary of decarbonisation levels achieved by national actions and low carbon projects identified in Greater Brighton

There has been a historic decrease in carbon emissions, mainly due to a successful greening of the electricity grid. Meaning in order for electricity generation to be of maximum value it has to be coupled with an electrification of both the heat and transport sectors.

The scenario presented shows a ~75% reduction in carbon emissions from the present day. Thus, additional action will be needed at either a national or local level (or a combination of both) to achieve full decarbonisation. The relative impacts of local and national policy is explored in Figure 10—2.

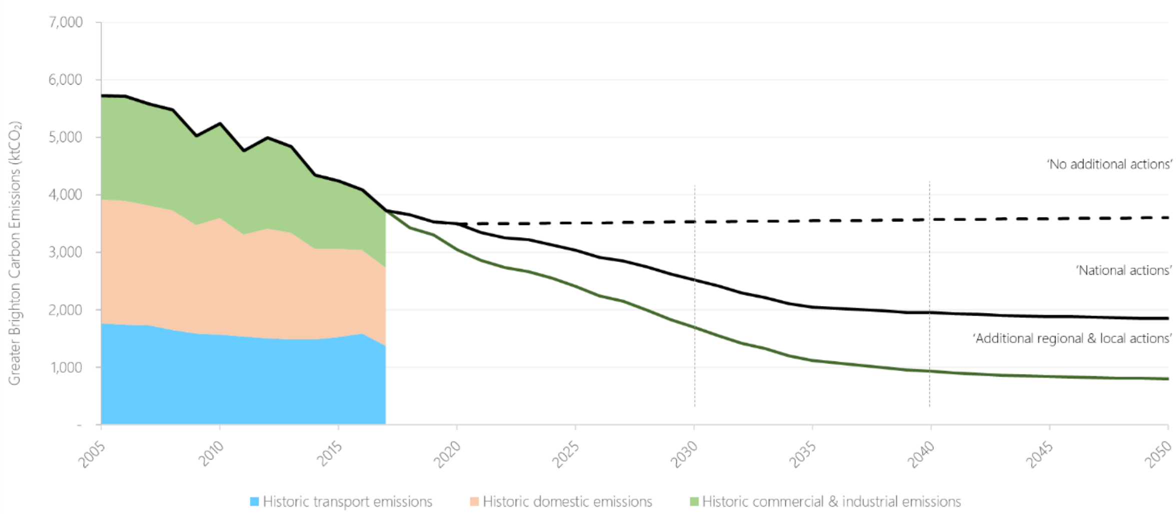

Figure 10—2 Impact of different policy approaches on decarbonisation in Greater Brighton

Figure 10—2 highlights that with no additional action there is a slight carbon growth, due to an increase in population and associated per capita emissions. National actions and policies achieve a reduction of ~1500 $ktCO_2$ per annum, comparing current and 2050 emissions. With additional local Greater Brighton based actions this drops by a further ~1000 $ktCO_2$, to just under 1000 $ktCO_2$. So even with an aggressive decarbonisation approach (particularly in terms of heat compared to national policy) further action is needed to reach the zero-carbon target locally, this is discussed in the section below.

10.2 Energy share

Examination of the energy share different demands that make up in the energy system helps to understand how transitions occur and where changes can be made to maximise decarbonisation. Based on analysis of the project pipelines and opportunities identified an example summary of the energy share for Greater Brighton projected to 2050 is presented in Figure 10—3.

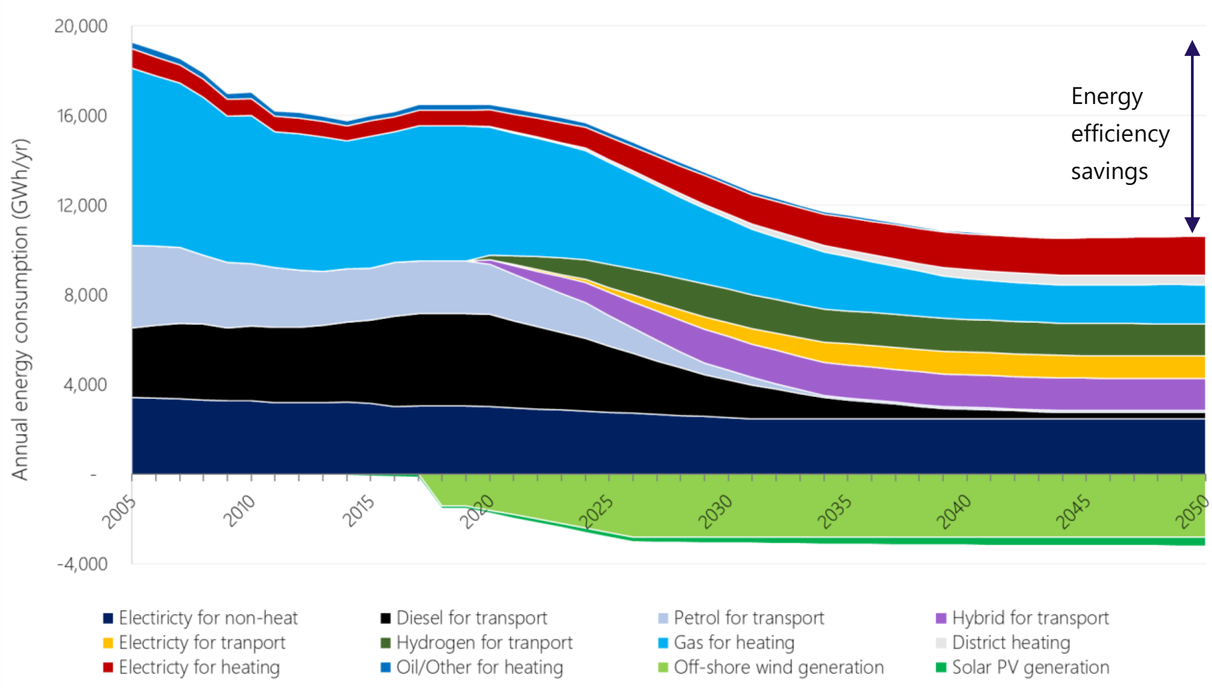

Figure 10—3 Energy share for different sectors

The offshore wind is provided by the Rampion offshore wind farm with the increase to 2027 coming from the planned extension of the site. Whilst the Rampion wind farm is not included in the carbon analysis it is illustrated in the energy share to give perspective to the relative contribution of solar PV. The modelled PV equates to over 300MW of additional installed capacity from current levels by 2050, compared to the 800MW of capacity for the Rampion (with the extension). The difference is exacerbated by the substantially higher capacity factor for offshore wind meaning each MW of capacity nearly four times the electricity will be generated in a year. However, solar PV can still have a very important part to play in the low carbon transition for Greater Brighton either through utilisation on site for small power and process demand or through decarbonising other vectors. This technology coupling for heat, e.g. providing power to heat pump systems, and transport, e.g. solar carparks and Riding Sunbeams, is seen as more beneficial than spilling electricity to the grid where, as Figure 10—3 illustrates, centralised offshore wind provides a more viable alternative.

In the scenario presented above there is still a high level of gas usage, some of this is due to centralised UK thermal generation, but the main element is the hybrid heat pump solution. This shows that there is a need for either hydrogen to replace natural gas or for a full transition to electric heat solutions in order to achieve net zero carbon.

Achieving net zero

In achieving a net zero energy system heat is currently seen as the largest barrier, due to the lack of centralised government pathway. In the Greater Brighton strategy this full decarbonisation of heat depends on either hydrogen replacing natural gas as back up for hybrid heat pump systems or a complete transition to electric heat.

The greater national guidance and legislation for transport means this is not as great a challenge, although this policy does allow for some retention of hybrid vehicles which would continue to contribute to carbon emissions. It should be noted the data upon which the electricity decarbonisation modelling is based still utilises a relatively small level of gas generation. Thus although electricity is currently the furthest vector along the road towards decarbonisation full decarbonisation is challenging and given that both heat and transport are decarbonising through electrification this issue is exacerbated. The main alternative is to either assume natural gas replacement with hydrogen for thermal generation or oversizing renewable generation in the Greater Brighton to create a high enough level of carbon savings to displace the carbon generation on the grid – however, this is considered a national rather than Greater Brighton solution.

In summary there are many actions Greater Brighton is well placed to undertake to move towards a zero-carbon energy system and to be leader in the national context. However, full decarbonisation is a challenge which needs more national input to address among other things some fundamental economic imbalances.

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